Table III. Chemical Compositions of Bagged Minus 6- Plus 50-Mesh Product

Nominal Grade	Nitrogen, % Total	HN_3	NO_3	P_2O_5, % Total	Citrate-insoluble	Water-soluble	Availability	K_2O, %	CO_2, %	SO_3, %	CaO, %	H_2O, %
14–11–11	14.7	6.8	7.9	11.7	0.1	<0.1	99	11.0	2.5	1.4	16.6	1.8
12–12–12	12.0	5.9	6.1	12.5	0.1	0.1	99	12.9	0.3	6.0	17.8	1.9
17–13–0[a]	17.7	8.4	9.3	14.3	0.8	0.0	94[b]	...	1.7	...	20.8	...
8–16–16	8.6	4.2	4.4	17.7	1.5	...	92[b]	15.8	...	...	...	0.7

[a] Made in bench-scale apparatus.
[b] Made without addition of sulfate.

states. A limited number of greenhouse tests indicated that the 17–13–0 product was as effective as concentrated superphosphate and ammonium nitrate when these materials were used to supply equivalent amounts of phosphorus pentoxide and nitrogen and when limestone was not added. When limestone was added, the first crop response of 17–13–0 was less than that of the standard materials, but the second crop response was about equal.

The products were in satisfactory condition after warehouse storage for 6 months in six-ply paper bags having two asphalt-laminated plies; it is believed that bags with only one asphalt-laminated ply, or equivalent, would be adequate.

Tests with a John Blue No. 30 screw-type fertilizer distributor showed the products to have satisfactory drilling characteristics before storage and after storage for 6 months.

Economics

Estimates indicate that the costs of producing 12–12–12 and 14–11–11 grade nitric phosphates by the carbon dioxide process should compare favorably with the costs of producing nitric phosphates by the other processes developed by TVA (*3, 6, 8, 9*). The process should be especially attractive to fertilizer manufacturers who produce their own ammonia, since carbon dioxide is available in abundance as a waste gas in most ammonia plants. The process should be economically attractive even if it is necessary to manufacture carbon dioxide.

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NITRIC PHOSPHATES

Economics of the Nitric Phosphate Fertilizer Processes

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Processes in which nitric acid is used to convert phosphate rock to forms suitable for fertilizer use (nitric phosphate processes) are being studied by the Tennessee Valley Authority. Much of the work has been carried through the pilot plant stage. This paper evaluates the economics of the nitric-phosphate processes under current market conditions based on the results of TVA pilot plant work. The evaluation involved preparation of estimates of investments, production costs, and wholesale selling prices in a given market area for the nitric phosphates and for mixed fertilizer of comparable grade, and comparison of the values obtained. The estimates indicated that, under current market conditions, the economic positions of the nitric-phosphate processes are favorable when compared with the conventional mixed fertilizer process for an annual volume of sales of 50,000 tons of product and that the position would be improved for larger volumes of sales.

NITRIC ACID has been used commercially in Europe for about 20 years to convert phosphate rock to forms suitable for fertilizer use. The processes, carried on principally in Norway, Holland, Germany, and France, were described by Hignett (*2*) and others (*1, 5, 8*).

Several of these nitric phosphate processes are being studied by the Tennessee Valley Authority. The study by TVA was undertaken because very little detailed information was available with regard to methods, equipment, and suitability of types of phosphate rock available in this country and because it appeared likely that improvements could be made in the processes. The processes appeared economically promising, and interest in them increased as the capacity for production of nitric acid was increased in this country and as a shortage of sulfuric acid developed. Much of the experimental work has been carried through the pilot plant stage (*2*, *3*, *9*).

The purpose of this paper is to evaluate the economics of the nitric phosphate processes under current market conditions based on the results of TVA pilot plant work. Two important characteristics of the current fertilizer market are its expected continued expansion and its dependence on sulfuric acid both to acidulate phosphate rock and to make ammonium sulfate, the predominant carrier of nitrogen in mixed fertilizer. The expected future shortage of low-cost sulfuric acid and the increasing demand for granular, high-analysis, high-nitrogen fertilizers make timely an evaluation of the nitric phosphate processes.

The method used in this evaluation involved the preparation of estimates of investments, production costs, and wholesale selling prices in a given market area for the nitric phosphates and for mixed fertilizer of comparable grade and the comparison of the values obtained. Estimated delivered wholesale selling price was used as the measure of relative economy of the processes. Wholesale price would be a measure of economy to farmers, because agronomic tests have shown that crop response is the same from application of nitric phosphates and mixed fertilizers, and to manufacturers of fertilizer because the same return on investment was used in the estimates for each process.

Description of Processes

The processes are shown schematically in the two flow diagrams of Figure 1. Four nitric phosphate processes as developed on a pilot plant scale by TVA were selected and are represented by one flow diagram because of their similarity with respect to equipment used and their similarly continuous flow patterns. The other flow diagram represents the mixed fertilizer process now in commercial use, which differs in several respects from the nitric phosphate processes.

The four nitric phosphate processes are similar in that each consists of mixing phosphate rock with nitric acid alone or with a mixture of nitric acid and phosphoric or sulfuric acids in agitated extraction vessels and transferring the slurry to other agitated vessels where gaseous anhydrous ammonia is added. Ammonium nitrate and dicalcium phosphate are formed, and the water content is kept sufficiently high to maintain fluid slurries. In each process the slurries are dried and appropriate potash salts are added to produce three-component fertilizers.

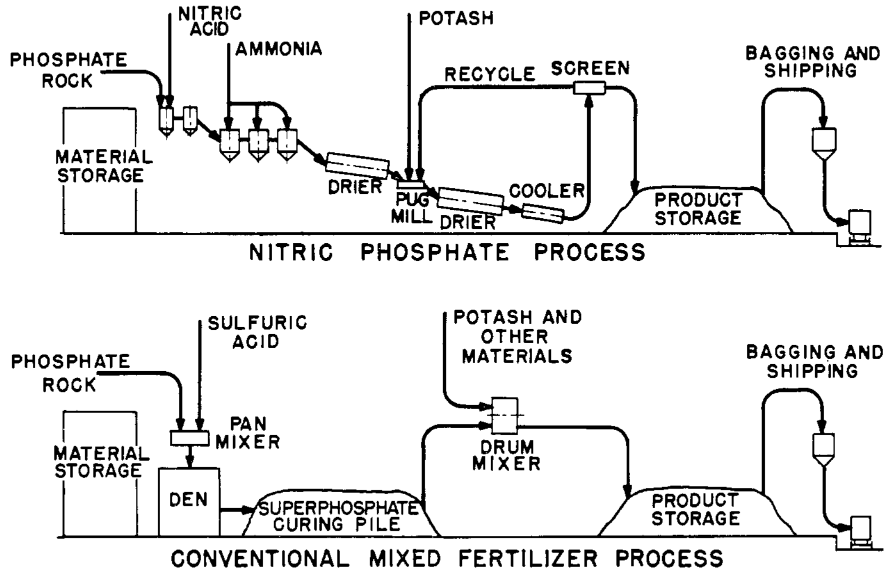

Figure 1. Nitric phosphate and conventional mixed fertilizer processes

Because phosphate rock contains more calcium than is required for the formation of dicalcium phosphate, some provision must be made to prevent this additional calcium from appearing in the final product as calcium nitrate, a very hygroscopic salt. The four processes differ principally in the materials added in each case to prevent the formation of calcium nitrate, and consequently the composition of each product is different. In process I, phosphoric acid is added in the extraction vessels to form additional dicalcium phosphate. In process II, sulfuric acid is added to form calcium sulfate. In process III, potassium sulfate is added in the first ammoniator and to the partially dried slurry to form calcium sulfate and potassium nitrate. In process IV, gaseous carbon dioxide is added to the slurry in the ammoniation vessels to produce calcium carbonate. The reactions and compositions of the products are discussed in more detail by Hignett and others.

Table I. Basic Assumptions for Estimates

1. Plant location	Sheffield, Ala.		
2. Plant capacities	50,000 and 200,000 tons/year		
3. Market area			
Small plant	250-mile radius		
Large plant	500-mile radius		
4. Costs of raw materials	Published market prices as of January 1953		
		Nitric Phosphates	*Mixed Fertilizer*
5. Operating time[a]			
Shifts/day		3	2
Days/week		7	6
% of scheduled time		90	90
6. Allowances for losses in process and for overage in grade, %			
N		5	2
P_2O_5		5	5
K_2O		3	3
7. Storage capacity, % of annual production		40	40

[a] Seasonal operation of bagging and shipping facilities.

Granular, homogeneous products are produced in each of the nitric phosphate processes by proper selection of equipment and control of the steps of drying, potash addition, screening, and recycling. These techniques are different in each process. All dryers are of the cocurrent flow, direct-fired rotary type. In process I, one high-temperature dryer is used and potash is added in a pugmill after the dryer. In processes II and III, two-stage drying (high and low temperature) is employed and potash is added in a pugmill between the stages. In process IV, two-stage drying (both low temperature) is used and potash is added to the slurry in the last ammoniator. All products are cooled in a rotary cooler before being screened. The fines and oversize from the screen are recycled to a pugmill between the drying stages in processes II, III, and IV and to a pugmill after the dryer in process I. The ratio of recycled fines to product is different in each case and is about 2.0, 4.0, 2.5, and 3.0 in processes I, II, III, and IV, respectively. The products are conveyed from the screen to the storage building.

The conventional mixed fertilizer process consists of mixing ground phosphate rock with sulfuric acid in a pan mixer in batches and storing these batches in a den until the mixture has solidified sufficiently for it to be conveyed to a pile, where it is cured for 6

Table II. Estimated Costs of Production of Nitric Acid for Nitric Phosphate Processes

Process	I	II	III	IV	II
Grade	14–14–14	11–11–11	12–12–12	12–12–12	11–11–11
Capacity of fertilizer plant, tons/year	50,000	50,000	50,000	50,000	200,000
HNO_3 required, tons/day	49	39	57	44	155
Investment, $	800,000	800,000	800,000	800,000	1,500,000
Item	*Cost per Ton of HNO_3, Dollars*				
Ammonia, 94% efficiency, 0.287 ton	23.53	23.53	23.53	23.53	23.53
Electricity, 260 kw.-hr. at 5 mills	1.30	1.30	1.30	1.30	1.30
Cooling water, 10M gal. at $0.05	0.50	0.50	0.50	0.50	0.50
Operating labor[a]	0.98	0.98	0.98	0.98	0.33
Maintenance	0.80	0.80	0.80	0.80	0.50
Catalyst, $1.50/ton	1.50	1.50	1.50	1.50	1.50
Depreciation, 7% of investment	3.49	4.44	3.03	3.94	2.08
Property tax, 1% of investment	0.50	0.63	0.43	0.56	0.30
Insurance, 1% of investment	0.50	0.63	0.43	0.56	0.30
Control	0.20	0.20	0.20	0.20	0.20
Plant overhead, 50% labor	0.69	0.69	0.69	0.69	0.29
Total per ton of HNO_3	33.99	35.20	33.39	34.56	30.83

[a] The average wage rate for operators in the nitric acid plants was $2.44 per hour. Labor required was 24 man-hours per day for both the 60-ton-per-day plant and the 180-ton-per-day plant.

weeks. The cured superphosphate is mixed in batches with potash, nitrogen carriers, and other materials in a revolving drum where the mixture is ammoniated with nitrogen solution. The product is crushed and screened and then conveyed to the storage building.

Nitric phosphates can be made with various ratios of nitrogen to phosphorus pentoxide. As the ratio is decreased, smaller amounts of nitric acid are used, more of the other acids are required, and the economic advantage of using nitric acid is decreased somewhat. Products having nitrogen–phosphorus pentoxide ratios as low as 0.5 were made by processes I and II in the pilot plant. A low-temperature drying step was required in process I in producing nitric phosphates having low nitrogen–phosphorus pentoxide ratios. In processes III and IV the ratio is limited to 1.0 or above by the stoichiometry of the processes. In process IV the ratio is 1.3 when nitric acid alone is used. The ratio may be lowered by adding sulfuric acid.

A plant food ratio of 1–1–1 was selected for all products included in the present evaluation because it is appropriate to compare the prices of fertilizers that have the same ratios of plant food. Increase in the ratios of nitrogen to phosphorus pentoxide and potassium oxide to phosphorus pentoxide over those used currently in the United States has been recommended widely, based on agronomic considerations, and the demand for the 1–1–1 ratio is increasing. Grades of nitric phosphates selected for the present evaluation were 14–14–14, 11–11–11, 12–12–12, and 12–12–12 for processes I, II, III, and IV, respectively. The 10–10–10 grade was selected for the conventional mixed fertilizer process. [Following the usual fertilizer practice, fertilizer grades given in this paper indicate the percentages of nitrogen (N), available phosphoric acid (P_2O_5), and potash (K_2O) by the first, second, and third numerals, respectively.]

One of the nitric phosphate processes that is not included in the present estimate involves the use of nitric acid, sulfuric acid, and anhydrous ammonia to produce fertilizers having ratios of nitrogen to phosphorus pentoxide of 0.5 or less (*4*). Typical grades would be 5–15–10 and 6–18–0. Pilot plant study of this process has not been completed. Work is being directed toward the use of the process in equipment such as is used in the conventional mixed fertilizer process and determination of the alterations required for use of this process in existing facilities. It is expected that less investment would be required than for the slurry-type processes. Preliminary estimates indicated that this process would be economically promising in comparison with mixed fertilizers of comparable grade.

Table III. Estimated Cost of Production of Phosphoric Acid for Nitric Phosphate Process I

Investment	$285,000
Capacity of plant	14 tons H_3PO_4 per day
Item	*Cost per Ton of H_3PO_4, Dollars*
Phosphate rock	32.18
Sulfuric acid	40.90
Operating labor	6.95
Maintenance	1.95
Electricity	0.49
Water, filtered	0.13
Water, scrubbing	0.31
Fuel	0.23
Property tax	0.61
Insurance	0.61
Depreciation	4.25
Supplies	0.10
Overhead	3.97
Total	92.68

Basic Assumptions for Estimates

The basic assumptions of plant location, plant capacities, and pricing basis are given in Table I. Other assumptions are discussed below.

Raw Materials It was assumed that the plants using nitric and phosphoric acids would manufacture these acids as a part of their operations, since these acids normally are used at the point of manufacture and are not sold as such in large quantities. These acids were charged to the fertilizer processes at cost, and the investments for the acid plants were included in calculating selling price. The estimated costs of producing nitric acid and phosphoric acid are detailed in Tables II and III.

The cost of ammonia to the processes was assumed to be the published market price (*7*) without freight. Although there is no commercial producer of ammonia at Sheffield, Ala., the price used might be typical of that used at many locations, since the location of ammonia plants is fairly widely distributed. The cost of sulfuric acid to the processes requiring it was assumed to be the published market price (*7*) without freight. Although there is no producer of sulfuric acid at Sheffield, the acid may be obtained from nearby sources at prices equal to or lower than the published price. For process IV it was assumed that the fertilizer plant would be operated in conjunction with an ammonia plant and that carbon dioxide could be obtained at the cost of recovery of the gas from the ammonia plant. Other materials were assumed as being purchased at published or known market prices and delivered from the nearest manufacturing point. No price discounts were included, but federal transportation tax was included. The use of Florida phosphate rock, 75% BPL grade (bone phosphate of lime), washed but unground, was assumed for the nitric phosphate processes. The same grade of rock was assumed for the mixed fertilizer process, but an estimated cost of grinding was included in the price. The costs of raw materials for each process are given in Table IV. The sources and freight costs of delivered raw materials are given in Table V.

Investments The estimated investment costs used in calculating the selling price of the product of each process are given in Table VI. The total investment includes cost of construc-

Table IV. Estimated Costs of Raw Materials for Production of Nitric Phosphates and Mixed Fertilizers

Process		I	II	III	IV	Mixed fertilizer	II	Mixed fertilizer
Grade of product		14–14–14	11–11–11	12–12–12	12–12–12	10–10–10	11–11–11	10–10–10
Capacity of plant, tons/year		50,000	50,000	50,000	50,000	50,000	200,000	200,000
Raw Material	*Unit Cost*	*Cost of Raw Materials, Dollars/Ton of Product*						
Phosphate rock	\$13.20/short ton for nitric phosphate processes and \$14.20 for mixed fertilizer[a]	3.05	4.45	4.84	4.84	2.33	4.45	2.33
Nitric acid	Charged at cost of production; varies with process	10.89	8.87	12.35	9.82	...	7.77	...
Ammonia	\$82.00/ton NH_3	7.54	5.90	4.51	6.29	...	5.90	...
Sulfuric acid	\$21.00/ton H_2SO_4	...	2.88	...	1.50	2.09	2.88	2.09
Phosphoric acid	\$92.68/ton H_3PO_4	8.71	...	...	...	...	...	...
Carbon dioxide	\$1.00/ton CO_2	...	...	...	0.06	...	...	...
Potassium chloride	\$40.50/ton	9.72	7.65	...	8.34	6.97	7.65	6.97
Potassium sulfate	\$51.55/ton	...	...	12.68	...	...	...	...
Ammonium sulfate	\$47.15/ton	...	...	...	...	16.83	...	16.83
Nitrogen solution	\$57.98/ton	...	...	...	...	4.06	...	4.06
Triple superphosphate	\$55.00/ton	...	...	...	...	5.45	...	5.45
Limestone conditioner	\$6.50/ton	...	...	...	...	0.33	...	0.33
Total cost of raw materials per ton of product		39.91	29.75	34.38	30.85	38.06	28.65	38.06
Average cost per unit of plant food		0.95	0.90	0.96	0.86	1.27	0.87	1.27

[a] The price of phosphate rock for the conventional mixed fertilizer process includes cost of pulverizing the rock.

tion of the process plants and working capital.

Nitric Acid Plants. It was assumed that a 60-ton-per-day nitric acid plant was built for each of the small nitric phosphate plants and that a 180-ton-per-day nitric acid plant was built for the large nitric phosphate plant. The plants were assumed to be operated for only a sufficient amount of time to supply the acid required for each process.

Phosphoric Acid Plants. It was assumed that a wet-process phosphoric acid plant (10 tons of acid phosphorus pentoxide per day) would be built to supply phosphoric acid for process I. The phosphoric acid would be produced and used at a concentration of about 38% H_3PO_4.

Nitric Phosphate Process Plants. The estimated cost of constructing each nitric phosphate plant having a capacity of 50,000 tons of product per year was \$1,500,000. The plant cost would be somewhat different for each process, but the variations would not be large enough to affect the comparisons made for the purpose of this paper. The estimated costs of process equipment and manufacturing buildings amounted to \$700,000. The estimated costs of railroads, land, engineering and contracting fees, provision for storage of raw materials, utility systems, offices, and laboratory amounted to the remaining \$800,000. The estimated cost of constructing the nitric phosphate plant having a capacity of 200,000 tons of product per year was \$4,000,000. It was assumed that this plant consisted of two trains, each having a capacity of 100,000 tons of product per year.

Mixed Fertilizer Process Plants. The estimated cost of constructing the mixed fertilizer plant having a capacity of 50,000 tons of product per year was \$700,000. Included were costs of process equipment for making superphosphate and for making mixed fertilizer, buildings, fees, etc. The estimated cost of constructing the plant having a capacity of 200,000 tons of product per year was \$1,900,000. It was assumed that this plant consisted of two trains, each having a capacity of 100,000 tons of product per year.

Product Storage Building. The cost of a separate building for storage of bulk product was included in each case. It was assumed that the building would be large enough to provide space for 40% of the annual production, the maximum amount of product that would be expected to be in storage at one time.

Working Capital. The estimates included as working capital the value of the average inventory of product and the value of 2 weeks' supply of raw materials. For the mixed fertilizer process, an additional amount equal to the value of 6 weeks' inventory of superphosphate in the curing pile was included.

Operating Costs

The estimated operating costs for each process are given in Table VII, and the assumptions used in arriving at these values are discussed below.

The estimated cost of operating labor included the salaries of shift foremen, operators, and laborers and the expense of other compensation such as a retirement plan, vacations, sick leave, shift differential, holidays, insurance, and merit awards. The basic rates of pay used in the estimates varied from \$1.43 per hour for laborers to \$2.19 per hour for shift foremen. The weighted average basic rate in each process plant was \$1.60 per hour. [The average hourly earnings in the fertilizer industry in 1952 was \$1.32, and the average for all manufacturing industries was \$1.61 (*6*).] The additional compensation factors amounted to 25% of the basic rate; therefore, the cost of operating labor was \$2.00 per man-hour. Separate schedules of operating labor requirements were prepared for each plant.

The maintenance of the plants would involve principally the work of a machinist and a pipe fitter and their helpers, and an electrician. A schedule of maintenance labor was prepared for each process. The average basic rate used was \$2.16 per hour. Adding an allowance for overtime work and 25% for the other

Table V. Market Prices and Sources of Raw Materials

Raw Material	Source	F.o.b. price (Dollars per Short Ton)	Freight cost (Dollars per Short Ton)	Delivered price (Dollars per Short Ton)
Phosphate rock, 75% BPL	Florida mines	5.36	7.84	13.20
Potassium chloride, 60% K_2O	Carlsbad, N. M.	25.20	15.30	40.50
Potassium sulfate, 50% K_2O	Carlsbad, N. M.	36.25	15.30	51.55
Ammonium sulfate, 20.6% N	Birmingham, Ala.	44.00	3.15	47.15
Nitrogen solution, 40.6% N	El Dorado, Ark.	48.72	9.26	57.98
Triple superphosphate, 48% P_2O_5	Tampa, Fla.	43.70	11.30	55.00
Limestone conditioner	Pelham, Ala.	(Delivered basis)		6.50

Table VI. Estimated Investment Costs for Plants for Production of Nitric Phosphates and Mixed Fertilizers

Process	I	II	III	IV	Mixed fertilizer	II	Mixed fertilizer
Grade of product	14–14–14	11–11–11	12–12–12	12–12–12	10–10–10	11–11–11	10–10–10
Capacity of plant, tons/year	50,000	50,000	50,000	50,000	50,000	200,000	200,000
Item	*Investment, Thousand Dollars*						
Nitric acid plant	800	800	800	800	...	1500	...
Phosphoric acid plant	285	...	...	...	...	...	...
Process plant	1500[a]	1500[a]	1500[a]	1500[a]	700	4000[b]	1900
Product storage building	500	500	500	500	500	1200	1200
Total plant investment	3085	2800	2800	2800	1200	6700	3100
Working capital	600	500	550	500	600	1800	2400
Total investment for pricing	3685	3300	3350	3300	1800	8500	5500

[a] Includes $700,000 for manufacturing buildings and equipment and $800,000 for railroads, land, utility systems, offices, laboratory, etc.
[b] Includes $1,900,000 for manufacturing buildings and equipment.

additional compensation factors gave a cost of maintenance labor equal to $3.00 per man-hour. It was assumed that the expense of materials used in maintenance was equal to the expense of maintenance labor.

It was assumed that each product would be packaged in a five-ply paper bag holding 100 pounds of fertilizer. All the products contain ammonium nitrate and would require protection from humid atmosphere to prevent caking. One ply would be moistureproof (such as an asphalt-laminated ply). Tests have indicated that such a bag would provide satisfactory protection from humid atmospheres for at least 6 months. Within this period of time the product ordinarily would be bagged, shipped, and used by the farmer.

It was assumed that natural gas and electricity would be supplied by distributors operating in Sheffield, Ala., and that a source of water would be near the plant. Natural gas with a heating value of 1000 B.t.u. per cubic foot was charged at 35 cents per 1000 cubic feet for use as fuel for the dryers. Electricity was charged at 5 mills per kw.-hr. The investment costs for pumps and filters for water were included in the cost of construction of the plants, and it was assumed that these would be operated by plant personnel. To cover other costs incurred in operating the water system, process water was charged at 15 cents per 1000 gallons and scrubbing or cooling water at 5 cents per 1000 gallons.

Included in the costs of analyses, yard handling, and supplies were costs involved in making appropriate tests and chemical analyses for control of the processes, switching railroad cars and moving trucks in the yard area, the cost of gasoline for Tructractors, and the cost of operating supplies and safety equipment.

Property tax was assumed to be 1% of plant investment per year, and insurance was assumed to be 1% of plant investment per year.

Depreciation was assumed to be equal to 7% per year of the investment cost of process plants and 3% per year of the investment cost of the product storage building.

The expenses of plant management, purchasing, accounting, operation of first aid and lunch stations, etc., were classified as plant overhead and were estimated to be 50% of the total cost of direct operating and maintenance labor.

Calculation of Wholesale Selling Price The estimated wholesale selling prices for each product are given in Table VIII, and the assumptions used in arriving at these values are discussed below.

The expenses incurred in selling, such as salaries of sales personnel and travel expenses, and expenses of general administration were grouped together and estimated to be $3.00 per ton of bagged product in each case.

Federal income tax was calculated as 52% of net earnings from each operation.

Return on investment after taxes was assumed to be 8% per year of the total investment, including working capital.

Wholesale selling price was estimated on a delivered basis and included freight of $5.00 per ton for the 50,000-ton-per-year distribution and $8.00 per ton for the 200,000-ton-per-year distribution as average freight costs.

Results of Estimates

The estimates indicated that under current market conditions the economic positions of the nitric phosphate processes are favorable when compared with the conventional mixed fertilizer process

Table VII. Estimated Operating Costs for Nitric Phosphate and Mixed Fertilizer Processes

Process		I	II	III	IV	Mixed fertilizer	II	Mixed fertilizer
Grade of product		14–14–14	11–11–11	12–12–12	12–12–12	10–10–10	11–11–11	10–10–10
Capacity of plant, tons/year		50,000	50,000	50,000	50,000	50,000	200,000	200,000
Item		*Operating Costs, Dollars/Ton of Product*						
Operating labor	Man-hr./ton. 1.46 and 0.87 for small and large N/P plants; 1.16 and 0.79 for mixed fertilizer	2.92	2.92	2.92	2.92	2.32	1.74	1.58
Maintenance		1.62	1.62	1.62	1.62	0.84	0.84	0.42
Bags	13.4 cents each	2.68	2.68	2.68	2.68	2.68	2.68	2.68
Fuel	Natural gas	0.55	1.21	0.81	0.81	...	1.21	...
Electricity	60 kw.-hr./ton	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Water		0.01	0.02	0.01	0.01	0.03	0.02	0.03
Analyses		0.33	0.33	0.33	0.33	0.20	0.33	0.20
Yard handling		0.20	0.20	0.20	0.20	0.20	0.20	0.20
Supplies		0.10	0.10	0.10	0.10	0.08	0.10	0.08
Depreciation		2.40	2.40	2.40	2.40	1.28	1.58	0.85
Property tax		0.40	0.40	0.40	0.40	0.24	0.26	0.16
Insurance		0.40	0.40	0.40	0.40	0.24	0.26	0.16
Plant overhead		1.87	1.87	1.87	1.87	1.37	1.08	0.90
Total operating cost per ton of bagged product		13.78	14.45	14.04	14.04	9.78	10.60	7.56
Total operating cost per unit of plant food		0.33	0.44	0.39	0.39	0.33	0.32	0.25

Table VIII. Estimated Delivered Wholesale Prices for Bagged Nitric Phosphates and Mixed Fertilizers

Process	I	II	III	IV	Mixed fertilizer	II	Mixed fertilizer
Grade of product	14–14–14	11–11–11	12–12–12	12–12–12	10–10–10	11–11–11	10–10–10
Capacity of plants, tons/year	50,000	50,000	50,000	50,000	50,000	200,000	200,000
Item	*Dollars per Ton of Bagged Product*						
Cost of raw materials	39.91	29.75	34.38	30.85	38.06	28.65	38.06
Operating costs	13.78	14.45	14.04	14.04	9.78	10.60	7.56
Total production cost	53.69	44.20	48.42	44.89	47.84	39.25	45.62
(Total production cost per unit of plant food)	(1.28)	(1.34)	(1.35)	(1.25)	(1.60)	(1.19)	(1.52)
Selling and administrative expense	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Federal income tax	6.39	5.72	5.80	5.72	3.12	3.68	2.38
Return on investment	5.90	5.28	5.36	5.28	2.88	3.40	2.20
Freight for delivery of product	5.00	5.00	5.00	5.00	5.00	8.00	8.00
Delivered wholesale price	73.98	63.20	67.58	63.89	61.84	57.33	61.20
Delivered wholesale price per unit of plant food	1.76	1.92	1.88	1.77	2.06	1.74	2.04
(Selling price, f.o.b. plant)	(1.64)	(1.76)	(1.74)	(1.64)	(1.89)	(1.49)	(1.77)

for an annual volume of sales of 50,000 tons of product and that the position would be improved for larger volumes of sales. The estimated delivered wholesale prices (Table VIII) of the nitric phosphates in the smaller market area were from 7 to 15% lower than the estimated delivered wholesale price of conventional mixed fertilizer. The estimated selling price of nitric phosphate by process II was 7% lower than the price of mixed fertilizer for the small area and 15% lower for the large market area.

The wholesale prices estimated in the present evaluations would be lower if discounts were included in the prices of raw materials. However, the relative positions of the processes would not be changed greatly, as the discounts could be expected to apply to all processes.

The favorable position of the nitric phosphate processes is due principally to the lower production costs of plant food by these processes. Inspection of the costs of raw materials for each process in Table IV shows that the average costs of raw materials per unit of plant food in the nitric phosphates are from 68 to 75% of the cost of materials in conventional mixed fertilizer. Although the conversion costs (Table VII) are the same or somewhat higher for the nitric phosphate processes, this factor is not nearly great enough to overcome the advantage of lower costs of raw materials. The production costs (raw materials plus conversion) are from 16 to 22% lower for the nitric phosphate processes at the lower level of production. Since the unit conversion cost is decreased with increased production and the unit cost of raw materials remains practically unchanged, the advantage for the nitric phosphates increases with increased plant capacity. For example, the cost by process II is 16% lower for the 50,000-ton capacity and 21% lower for the 200,000-ton capacity than the cost by the conventional mixed fertilizer process.

The difference in the estimated production costs of the nitric phosphate processes was small and varied from $1.25 to $1.35 per unit for the small plants. Relative costs probably would vary with location and available facilities.

The plant investment required for the conventional mixed fertilizer process was estimated to be about one half of that estimated for the nitric phosphate processes, considering only the facilities included in the present study. However, it has been estimated that the total plant investment for the mixed fertilizer route would be about 80% of that for the nitric phosphate route if all plants required to produce plant food by both routes were considered (such as ammonia plant, solution plant, and ammonium sulfate plant). If the additional investment in transportation facilities, granulation equipment, and working capital were included for the mixed fertilizer route, the investments by each route would not be greatly different.

The present estimates do not include in the price of conventional mixed fertilizer the cost of granulation of the mixture to make its physical condition comparable with the granular, homogeneous condition of the nitric phosphates. Inclusion in the estimates of equipment for granulation of mixed fertilizers and provision for operation and maintenance of this equipment would increase the estimated wholesale price of conventional mixed fertilizer by about 5% and would increase further the advantage of the nitric phosphates.

The basic reason for economy in the nitric phosphate processes lies principally in the dual function of nitric acid in both acidulating phosphate rock and supplying nitrogen as plant food in the products. This procedure reduces or eliminates the traditional requirement of sulfuric acid and also makes possible the direct use in the processes of anhydrous ammonia, the cheapest source of fixed nitrogen. The use of ammonia instead of ammonium sulfate results in more highly concentrated products and in economy in transportation, since less inert materials are carried in delivery of raw materials to the process, storage, processing, and delivery of product.

Limited sulfur reserves and increasing demand for fertilizers indicate that large quantities of low-cost sulfuric acid may not be available in the future. Sulfuric acid from nonsulfur sources probably will be more expensive. Therefore, the economic advantage of nitric phosphates is expected to increase in the future.

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