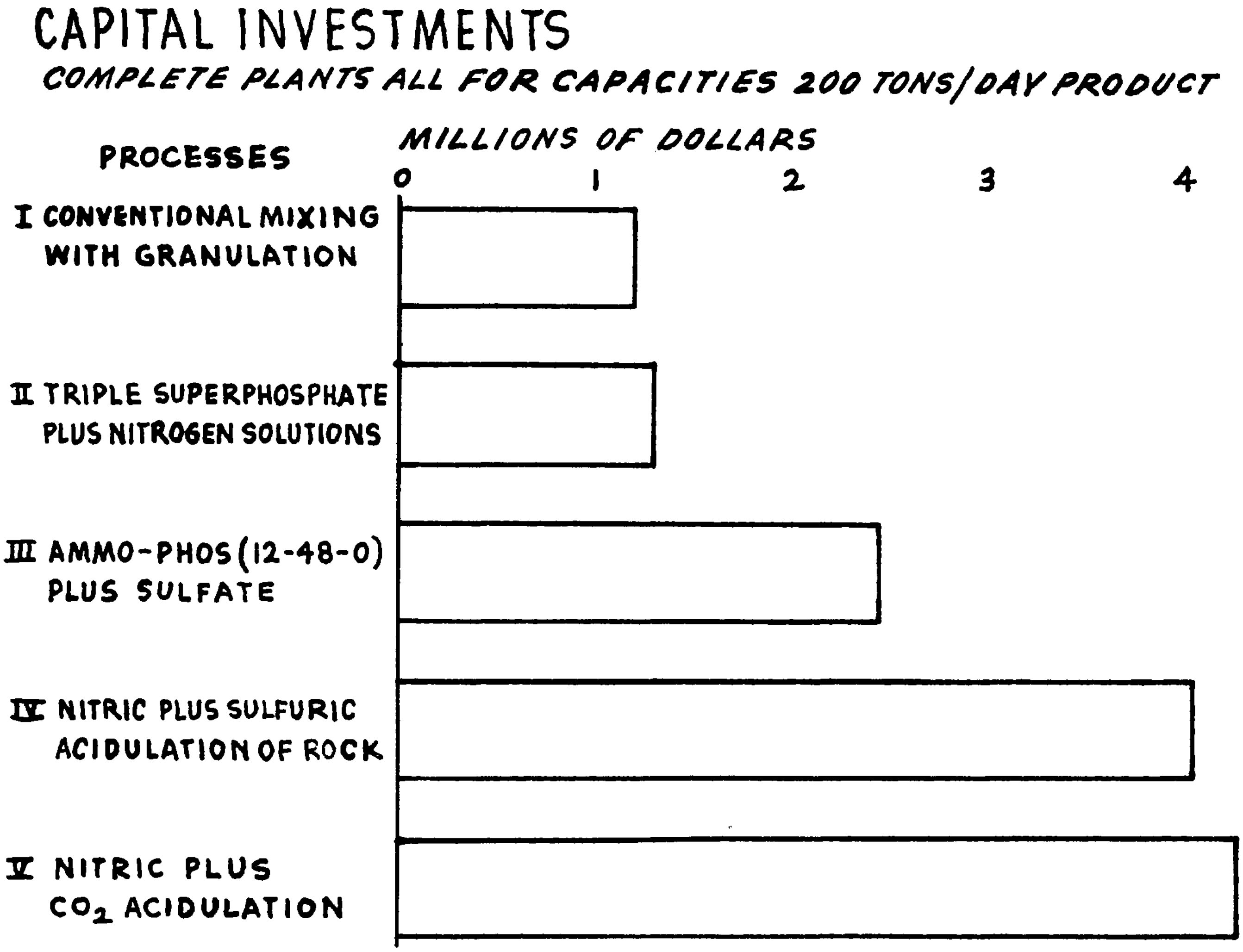

Figure 1

Economics of High Analysis Fertilizer Manufacture

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The conventional fertilizer manufacturer is in a good competitive position, if he minimizes losses, controls quality, granulates well

All of us are aware that the depletion of soils, the demands for higher farm production, and increases and shifts in population have given new impetus to the use of fertilizers in recent years. This new emphasis has placed a burden on existing manufacturers and has lured newcomers into the industry, but it has also done something else. It has prompted serious consideration for the manufacture of higher-analysis fertilizers—fertilizers which will yield greater production of crops and pasture lands per ton than ever before.

The manufacturer of high-analysis materials requires the utilization of technological advances and improvements that have commanded the attention of chemists and chemical engineers throughout the world. High-analysis processes have been developed in Europe and refined and improved in this country (*1, 2*). Also, several conventional processes have been modified to produce high-analysis materials.

Many of the 1300 conventional fertilizer manufacturers in the United States are wondering if these new processes and technological advances will destroy their competitive positions in the field and thus force them out of business (*8*). Since many of these conventional mixers are not large enough to justify or maintain sufficient technical staffs to keep them first in the industry, their apprehension regarding the future is magnified. This paper endeavors to examine the economics of high-analysis fertilizer manufacture with emphasis on process evaluation, raw materials, finished product formulations, and plant location. It may assist the conventional fertilizer manufacturer to determine his competitive position and to decide what action may be taken.

For those unfamiliar with fertilizer, complete fertilizers usually contain three major components—nitrogen, available phosphate expressed as P_2O_5, and potassium expressed as K_2O. These components are brought together in varying proportions as dictated by soil requirements and buying habits. Rather than saying so many pounds of each material, the industry has now adopted the term *unit*, which represents 20 pounds of plant food. A fertilizer mixture designated as a 1-1-1 formulation means equal ratios of N, P_2O_5, and K_2O.

For the purpose of this study the accepted line of demarcation for high and low analysis fertilizers is 33 total plant food units or higher per ton of mixed goods. Only the highest analysis which each process used in this study is capable of making has been considered. Each projected plant is designed to produce 200 tons per day of granulated product as any one of the three ratios 1-1-1, 1-2-1, or 1-3-1.

First, let us consider the processes selected. They are either used extensively in this country or are under serious consideration for use. Comments regarding their merits and state of development are appropriate.

Conventional Mixing with Granulation (Process I)

The raw materials, triple superphosphate (*4*), anhydrous ammonia, nitrogen solutions, ammonium sulfate, and potassium chloride, are brought together in correct proportions in a batch mixer (*7*). These batches are put into granulation equipment where they also are sized, dried, and cooled. Most granulation equipment consists of a rotary dryer and cooler and screens for sizing the small granules of fertilizer. The product is then packaged in 80- to 100-pound bags for shipment.

Most conventional mixing plants, however, are not now equipped with granulation; rather, the batched product is allowed to cure in piles. Since there is an increasing demand for granulated fertilizers, many conventional mixers are endeavoring to install granulation equipment. While much attention is being given to the improvement of conventional mixed fertilizer plants, the art is fairly well developed and readily available. The next process represents a desirable improvement in conventional mixing.

Triple Superphosphate Plus Nitrogen Solutions (Process II)

This process is conducted in essentially the same equipment as process I; except that the higher solution phase brought about by the exclusive use of ammonia and nitrogen solutions (ammonia–ammonium nitrate in water solution) as the source of nitrogen renders the batch mixes impractical. A continuous ammoniator recently developed and introduced by TVA may be used in this process. Thus by the elimination of ammonium sulfate it is possible to raise the analysis approximately 25% and produce a good granule product. This process modification has been piloted by at least one manufacturer and is believed possible in part because of the modified physical characteristics which granulation gives the material. It offers significant economic advantages but as yet has not been thoroughly developed (*10*).

Ammo-Phos Plus Ammonium Sulfate (Process III)

Phosphate rock is acidulated with sulfuric acid and calcium sulfate is filtered off, leaving phosphoric acid. This acid is treated with ammonia to form ammonium phosphate. Additional sulfuric acid and ammonia, together with potassium chloride, are added to produce the required formulations. The material is granulated and bagged for shipment. The process is being used in this country and in Canada and is available for purchase from at least two engineering companies—Dorr Co. and Chemical Construction Co.

Ammo-Phos Plus Nitrogen Solutions (Process IIIA). The difference between this process and that with ammonium sulfate is that the additional nitrogen required for high-nitrogen formulations is introduced in the form of nitrogen solutions. These nitrogen solutions show an economic saving over the use of ammonia and sulfuric acid and substantially upgrade the analysis. This modification has not been proved in any commercial plant. While we see no reason why it should not be feasible, some risk would be attached to its adoption prior to further pilot plant work.

Nitric Plus Sulfuric Acid Acidulation (Process IV)

This is the process more than any of the others which has aroused the apprehension of the small conventional mixed fertilizer manufacturer. The capital investment required for process equipment and necessary supporting facilities is approximately $4 million, and this investment is beyond the means of most small mixed fertilizer manufacturers. Numerous claims for raw material savings have been made for this process and from the standpoint of raw material alone some of these claims are justified.

Processes using nitric acid alone and in combination with sulfuric acid for acidulating phosphate rock have been used in Europe for many years. Sulfur shortages with attendant increases in price have more than any other one factor caused the fertilizer industry in this country to look closely at this process. TVA has done a great deal of work on nitric-sulfuric acidulation and Allied Chemical & Dye Corp. has at least one commercial plant in operation and others projected (*1*, *2*, *3*, *9*).

Phosphate rock is treated in multiple vessels with ammonia and nitric and sulfuric acids. Potassium chloride is added and a product ratio of 11-11-11 is obtained. If 1-2-1 and 1-3-1 ratios are desired, additional P_2O_5 must be added as triple superphosphate. Raw material advantages which are obtained in 1-1-1 ratios are somewhat offset in higher ratios of P_2O_5. Higher investment and processing cost, and a less flexible plant offset the initial raw material advantage of the process. The process has been proved commercially and is available.

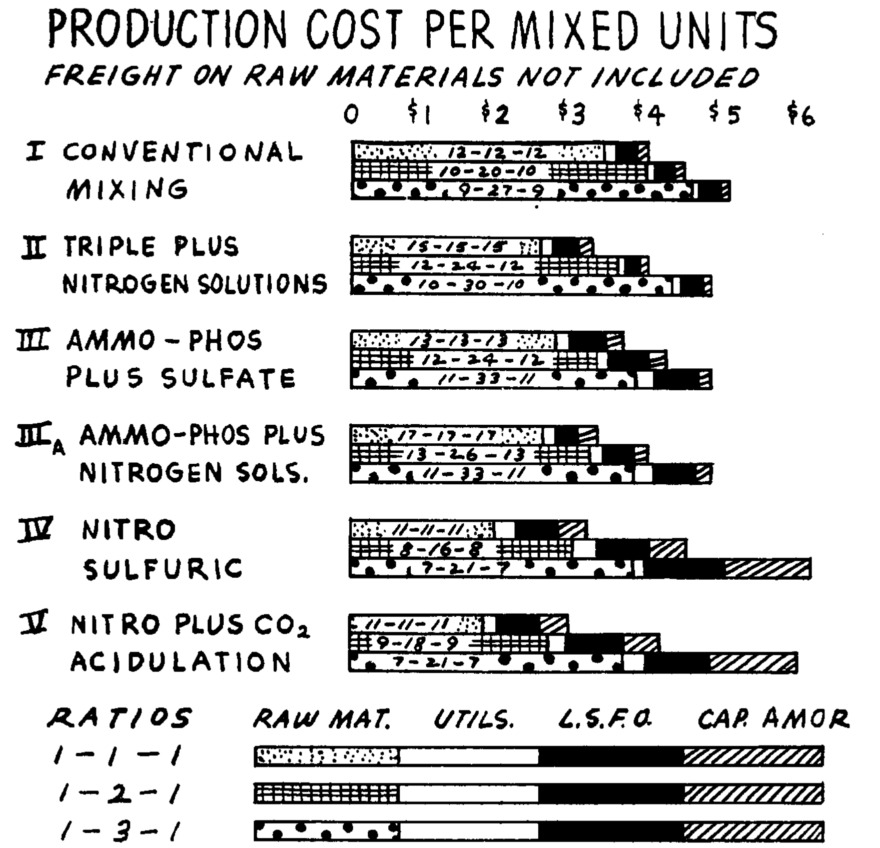
Nitric Plus CO_2 Acidulation (Process V)

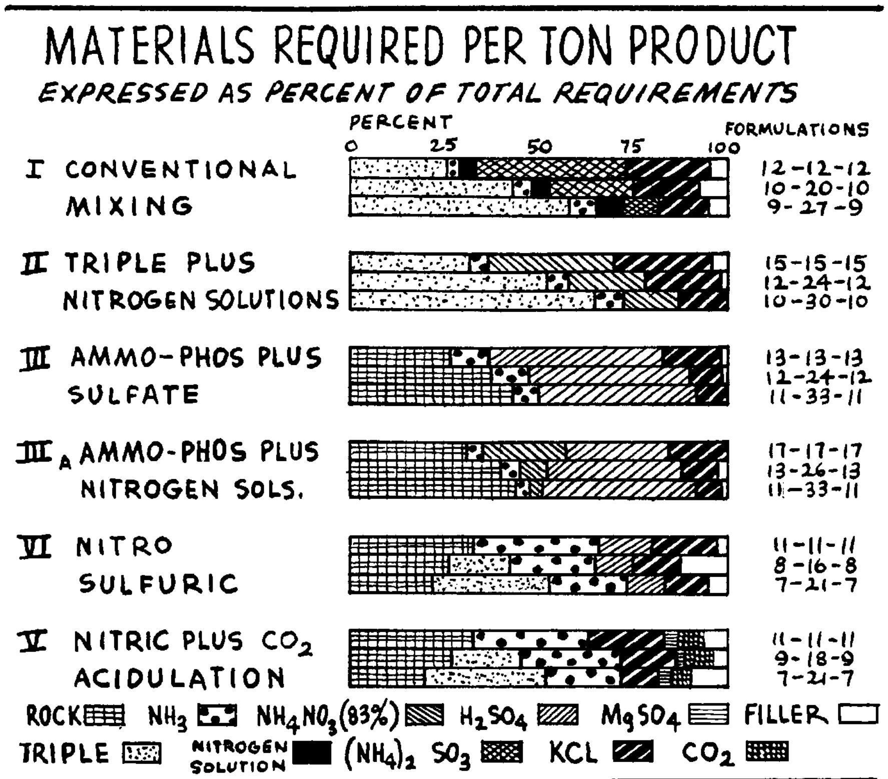
This process is similar in many respects to that above. Carbon dioxide gas instead of sulfuric acid is used with nitric acid to acidulate the phosphate rock. A small amount of magnesium sulfate is added to provide the sulfate radical which improves the granular form of the product (*6*). This process is included because of the attention currently given it by a number of manufacturers. Total production costs are slightly less than in process IV (*5*).

The limitations which apply to the above process also apply to this one. In addition it should be located near a cheap source of carbon dioxide gas. The process is in commercial operation in Europe and is available to American manufacturers; however, there are no commercial plants in this country to date.

Plants for each of these processes have been designed with equal capacities of 200 tons per day of product and on a comparable engineering level. They represent complete plants including all process facilities, one month's storage for raw materials, and four months' product storage. Capital investment in millions of dollars for each plant is shown in Figure 1. Note that the conventional mixer has considerably less in plant investment.

From the standpoint of raw material costs only, the conventional mixer appears to be in a very unfavorable position. However, let us consider the effect of all





Top, Figure 2; Bottom, Figure 3

other manufacturing costs on the total production costs for each of the products by each process.

A comparison of production costs by each process and for each formulation has little significance unless these production costs can be put on a common plant food basis. Since the maximum analysis which each of the processes can produce varies, depending upon the process, we have found it necessary to introduce a concept of mixed units in which costs for all 1-1-1, 1-2-1, and 1-3-1 ratios can be compared. Comparison of quantities and costs per mixed unit for each of the different processes must be made in the same ratio. This mixed unit represents a mass of fertilizer containing, for instance in the case of a 1-1-1 ratio, 20 pounds of N, 20 pounds of P_2O_5, and 20 pounds of K_2O. Likewise for all 1-2-1 ratios a mixed unit represents a mass of fertilizer containing 20 pounds of N, 40 pounds of P_2O_5, and 20 pounds of K_2O. The cost of one mixed unit is determined by dividing the total cost per ton by the analysis of N in the formulation. For example, if the production cost of a 12-24-12 is $60 per ton, then the cost of one mixed unit is 12 divided into 60 or $5.00. This mixed unit contains 20 pounds of N, 40 pounds of P_2O_5, and 20 pounds of K_2O. With this concept in mind, total production costs including raw materials, utilities, labor, supplies, factory overhead, and capital amortization have been calculated for each process and each formulation. Raw materials have been priced into the process at market price f.o.b. their source. Since freight on these raw materials varies with location and since plant locations are considered separately, processing costs are compared less any freight on raw materials. Unit costs for utilities and labor have been assumed to be the same regardless of location. Factory overhead is 50% of labor and supplies in each case. Capital amortization is based on 15 years depreciation. A comparison of production costs per mixed unit for each process less freight on raw materials is shown in Figure 2, with the different shadings showing the relative magnitude of each item of cost.

RAW MATERIAL COST

	$/Ton @ Source
Phosphate rock (34% P_2O_5)	5.80
Triple superphosphate (46% P_2O_5)	41.86
Anhydrous ammonia (82.5%)	82.00
Anhydrous for HNO_3	24.60
Nitrogen solution (37% N)	45.50
83% ammonium nitrate (29% N)	52.00
Ammonium sulfate (20.5% N)	49.50
Sulfuric acid 66° B'.	20.00
Potassium chloride (60% K_2O)	25.80
Magnesium sulfate	43.00
Carbon dioxide gas filler	4.00

Figure 4

Note particularly the relative production costs of processes I, II, and IV. Contrary to some recent opinion, the conventional mixer, when considering all manufacturing costs, is in a very good competitive position. If modifications required for process II were put into effect, his production costs for 1-2-1 and 1-3-1 ratios of materials would be lower than those for any other process while his production costs for 1-1-1 ratios would be equal to that of process IV. Also a slightly higher analysis of product is possible.

The percentage of each of the raw materials required for each of the processes and for each formulation is shown in Figure 3.

The market prices per ton of these raw materials at their sources and at the time of this study are shown in Figure 4.

Because of the very large tonnages of raw materials required, plant locations and freights are important considerations. We have chosen 7 different locations on the basis of raw materials, supply, markets, and transportation facilities. Further, it is assumed that the total output of a plant can be sold within a radius of 300 miles or approximately $5.00 per ton freight charges.

The next variable which we sought to determine was the effect of freight on raw materials for each of the processes and formulations at each location. This posed the problem of examining in excess of 126 different cases, the complete results of which would only serve to confuse the presentation of this study. Surprisingly enough, the total freight on raw materials for each of the different processes is about the same when considering these processes all at the same location. But the effect of total raw material freight at different locations is substantial. Also, raw material freight costs are affected but to a smaller extent when the formulation is changed. Freight charges for raw materials used in process II are representative of those of the other processes. Therefore, process II will be used to show the effect of location on production costs. The maximum difference in production cost due to location and formulation is shown in Figure 5. Note this maximum difference due to location is from $5.00 to $10 per ton of product depending on the formulation ratio being manufactured.

So far we have examined capital investments, component and total production costs, and the effect of location for each of six processes. It now can be concluded that the fertilizer manufacturer using either conventional mixing with granulation or a modification such as process II, can produce higher analysis fertilizers at as low or lower cost than can the mixer which uses one of the more expensive alternate processes. The next important considerations are relative profits and payouts realized on the capital invested.

Total production costs and cash sales prices for all products differ with plant locations. It is this difference between production costs and cash sales prices of products which we call operating margins. Since operating margins must provide for taxes, management's expense, including sales and profit, it is important to determine the locations of greatest operating margins.

Cash sales prices for the same product differ at each location. Figure 6 shows the cash sales prices for all products delivered to dealers at the locations in

EFFECT OF LOCATION ON PRODUCTION COSTS

PRODUCTION COSTS INCLUDE FREIGHT ON RAW MATERIALS

PROCESS II TRIPLE PLUS NITROGEN SOLUTIONS

LOCATIONS	T. FLA.	V. MISS.	M. KAS.	H. KY.	K. IA.	S. WASH.	P.A. TEX.	MAX. DIFF.
TOTAL PRODUCTION COSTS	$/TON	$/TON	$/TON	$/TON	$/TON	$/TON	$/TON	DUE TO LOCATION
FORMULATIONS 15-15-15	$55.54	$51.49	$53.59	$56.29	$56.44	$62.14	$53.59	$10.65
12-24-12	$55.57	$53.41	$56.41	$57.73	$57.97	$60.97	$54.01	$7.56
10-30-10	$55.29	$54.69	$58.19	$58.49	$59.09	$59.99	$54.29	$5.70
MAX. DIFF. DUE TO FORMULATION	$0.28	$3.20	$4.60	$2.20	$2.65	$2.15	$0.70	

CASH SALES PRICES ALL PRODUCTS

DELIVERED TO DEALERS

PRODUCTS	$/TON HIGH		$/TON LOW	
RATIOS	LOCATIONS	$/TON	LOCATIONS	$/TON
1-1-1				
17-17-17	SEATTLE, WASH.	$112.71	PORT ARTHUR, TEX.	$96.90
15-15-15	"	99.45	"	85.50
13-13-13	"	86.19	"	74.10
12-12-12	"	79.56	"	68.40
11-11-11	"	72.93	"	62.70
	MAX. VARIATION $15.81/TON			
1-2-1				
13-26-13	"	$117.26	"	$89.44
12-24-12	"	108.24	"	82.56
10-20-10	"	90.20	"	68.80
9-18-9	"	81.18	"	61.92
8-16-8	"	72.16	"	55.04
	MAX. VARIATION $27.82/TON			
1-3-1				
11-33-11	"	$125.51	"	$96.80
10-30-10	"	114.10	"	88.00
9-27-9	"	102.69	"	79.20
7-21-7	"	79.87	"	61.60
	MAX. VARIATION $28.71/TON			

OPERATING MARGINS

ANNUAL GROSS SALES LESS PRODUCTION COSTS

PROCESSES	PRODUCT RATIOS	LARGEST MARGINS		SMALLEST MARGINS	
		LOCATION	$/YEAR	LOCATION	$/YEAR
	1-1-1				
I	12-12-12	MILITARY, KAS.	$1,481,700	HENDERSON, KY.	$1,069,860
II	15-15-15	"	2,878,260	PORT ART., TEX.	2,106,060
III	13-13-13	"	1,891,560	SEATTLE, WASH.	999,240
IIIA	17-17-17	"	3,047,880	PORT ART., TEX.	1,948,320
IV	11-11-11	"	2,061,180	"	1,415,040
V	11-11-11	"	2,139,720	"	1,529,880
	1-2-1				
I	10-20-10	SEATTLE, WASH.	$2,209,020	PORT ART., TEX.	$1,186,020
II	12-24-12	"	3,112,820	"	1,884,300
III	12-24-12	HENDERSON, KY.	2,500,080	"	1,161,600
IIIA	13-26-13	"	2,826,780	"	1,402,500
IV	8-16-8	"	1,670,460	"	793,980
V	9-18-9	SEATTLE, WASH.	2,298,780	"	1,217,700
	1-3-1				
I	9-27-9	SEATTLE, WASH.	$3,028,080	PORT ART., TEX.	$1,834,140
II	10-30-10	"	3,571,261	"	2,224,860
III	11-33-11	TAMPA, FLA.	2,777,940	"	1,717,980
IIIA	11-33-11	"	2,785,200	"	1,717,980
IV	7-21-7	SEATTLE, WASH.	1,987,260	"	1,054,020
V	7-21-7	"	2,125,860	"	1,114,080

Top, Figure 5; Center, Figure 6; Bottom, Figure 7

PROFIT AND LOSS AND PAY OUT CALCULATION

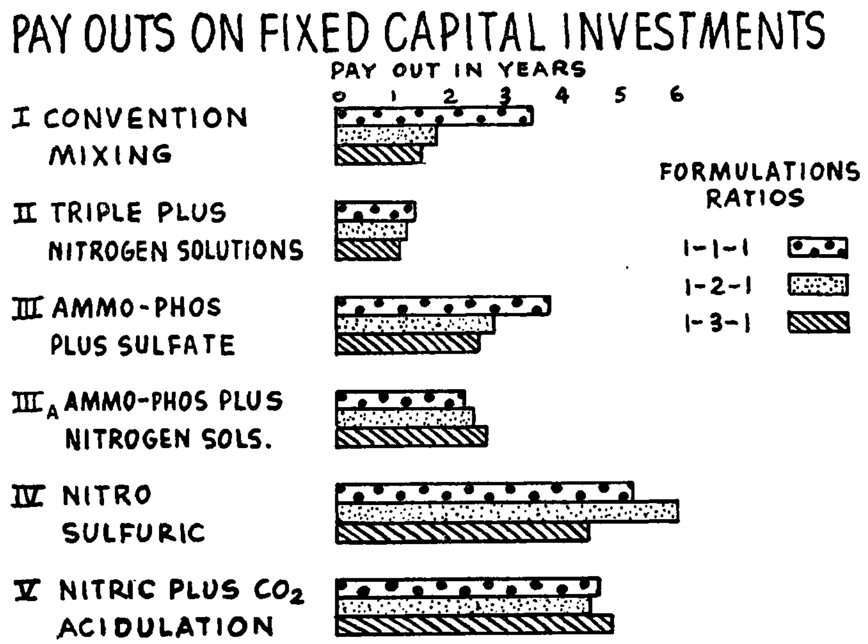
PROCESSES: II TRIPLE PLUS NITROGEN SOLUTIONS
PRODUCT: 12-24-12 @ 200 TONS PER DAY
PLANT LOCATION: SEATTLE, WASH.

GROSS SALES		\$ 7,143,840
FREIGHT @ \$ 5.00/TON PRODUCT		330,000
NET SALES		\$ 6,813,840
PRODUCTION COSTS	\$ 4,024,020	
OTHER EXPENSES (@ 10% NET SALES)	681,384	
TOTAL OPERATING EXPENSE		\$ 4,705,404
GROSS PROFIT		\$ 2,108,436
NET PROFIT (AFTER 55% TAXES AND INSURANCE)		948,796
DEPRECIATION THROWBACK		86,400
PAY OUT NET INCOME		\$ 1,035,196

PLANT INVESTMENT \$ 1,296,000

PAY OUT ON FIXED INVESTMENT

$$\frac{\$\,1{,}296{,}000}{\$\,1{,}035{,}196} = 1.25 \text{ YEARS}$$



Top, Figure 8; Bottom, Figure 9

which these prices are the lowest and the highest.

All other locations fall intermediate to these prices. Knowing the production costs and cash sales prices for each location, we were able to calculate operating margins. The locations at which the operating margins are largest and smallest are shown in Figure 7.

A location pattern emerged which indicates the Tri-State area around Joplin, Mo., the Pacific Northwest, and Evansville, Ind., to be preferred locations, while the East Texas, Gulf Coast area is less desirable.

Profit and loss and payout calculations which included total operating expenses, taxes, depreciation, and profit were made for each process at each location. Figure 8 is an example of these calculations.

We now know the relative profit position which the conventional mixer may expect with efficient operation and also the payout on fixed investment. Payouts on fixed capital investment for each of the processes operating at their most favorable locations are shown in Figure 9.

In conclusion, the three processes around which much current controversy exists are process I (conventional mixing using ammonium sulfate) as the major source of nitrogen, process II (triple superphosphate plus nitrogen solutions as the major source of nitrogen), and process IV (rock acidulation with nitric and sulfuric acids and ammonia). This process shows substantial savings in raw materials but other manufacturing costs offset this advantage. Low capital investment, equal or lower production costs, operational and formulation flexibility together with increased analysis show processes I and II to be highly competitive and much more desirable from the standpoint of invested capital.

Various formulations which can be made by process II will require nitrogen solutions containing anhydrous ammonia, ammonium nitrate, and water tailor-made for the product. Anhydrous ammonia and 83% solution of ammonium nitrate in water were used as nitrogen solutions in this study. However, solutions containing various percentages of ammonium nitrate or urea and water could also have been used without appreciably changing the economics. These various nitrogen solutions will be required since 83% solution of ammonium nitrate at normal temperatures solidifies in shipment and, therefore, is not an item of commerce. Depending upon the formulation and production rate it may be desirable to install a small solution stripper which will permit adjusting standard nitrogen solutions to those required for various formulations.

Based on the conclusions of this study, we believe the conventional fertilizer manufacturer's competitive position is good. However, he should carefully evaluate his operating techniques to minimize losses and to obtain quality control and good granulation. If this is done, the conventional fertilizer mixer is in a sound competitive position with others who may choose to produce their product by one of the alternate processes. If nitrogen solutions are used rather than ammonium sulfate, production costs can be reduced approximately \$10 per ton and the analysis raised substantially.

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