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DC3674

Distribution LIMITED

ID/WG.99/23
4 July 1972

Original: ENGLISH

United Nations Industrial Development Organization

Second Interregional Fertilizer Symposium

Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item III/11

COMPARATIVE PRODUCTION COST OF FERTILIZERS MADE BY NITROPHOSPHATE PROCESSES AND BY CONVENTIONAL SULPHUR-BASED PROCESSES

by

United Nations Industrial Development Organization
Vienna
Austria

id.72-4209

During the past ten years at least six different processes have been developed in order to produce nitrophosphate fertilizers with high water solubility of the phosphorus component. All of these processes seek to separate the phosphoric acid and calcium nitrate which are the two principal components in the phosphate rock-nitric acid attack solution.

These processes may be classified into one of three major categories:

1. Calcium nitrate crystallization processes (Norsk Hydro and Chemoprojekt/Bamag);

2. Phosphoric acid extraction processes (Typpi Oy);

3. Calcium sulphate precipitation processes (Stamicarbon, Chemico, Foster Wheeler and others) (also called ammonium sulphate recycle process).

Four of these processes are described in papers at this Symposium.

The basis for increased interest in nitrophosphate processes during the past six to eight years has been the high price of sulphur in the recent past. A few years ago sulphur prices were as high as $40 per ton f.o.b. Gulf of Mexico and other production points, although the price of sulphur has dropped greatly since then. The future of sulphur will be discussed in a later paper at this Symposium. Nitrophosphate processes can produce N-P fertilizers over a range of compositions, such as 28-14, 24-24, 20-30, 14-42, etal , without the use of any sulphur. This is clearly an attractive approach to fertilizer production when sulphur is high in price, but it becomes less attractive at lower sulphur price levels.

It is the purpose of this brief paper to compare the cost of production of N-P fertilizers by several nitrophosphate processes with the cost of production of the same N-P fertilizer by a process using sulphur (via sulphuric acid and phosphoric acid). If production costs are equal, sulphur-based processes are probably to be preferred since they are more flexible than nitrophosphate processes. Nitrophosphate processes are relatively inflexible and this is a drawback to their widespread use unless they have a substantial production cost advantage. All

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SUMMARY

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During the past ten years at least six different processes have been developed in order to produce nitrophosphate fertilizers with high water solubility of the phosphorus component. All of these processes seek to separate the phosphoric acid and calcium nitrate which are the two principal components in the phosphate rock-nitric acid attack solution.

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Four of these processes are described in papers at this Symposium.

The material and energy inputs of all these processes are comparable. Little information on capital costs of plants utilizing these processes is available. Estimates of nitrophosphate plants producing 1,400 tons per day of a 28-14-0 product run from $ 5 to $ 10 million, battery limits. Therefore there is no basis for knowing at this time which of these processes would have the lowest capital cost and/or the lowest production cost. Using an assumed capital cost of $ 7,500,000 for a 1,400 tons per day plant, we

have estimated the production cost of 28-14-0 by any of these processes at $ 25 per ton.

This cost can be compared with the production cost of a plant producing 28-14-0 by the conventional sulphur-sulphuric acid -- phosphoric acid -- nitric acid -- ammonia process. If we assume the capital cost of such a plant with a capacity of 1,400 tons per day to be $ 7.5 million, also, the production cost of 28-14-0 comes out to $ 25.00 if the price of sulphur is $ 5.00 per ton. Therefore by this rough calculation it appears that any of the nitrophosphate processes will have a lower cost of production for a 28-14-0 product than a sulphur-based process whenever the price of sulphur is more than $ 5.00 per ton.

It must be emphasized that this calculation is based on several very broad assumptions and also that it relates only to the particular 28-14-0 product. For other product compositions the relative production costs might be significantly different.

nitrophosphate processes yield a total product, including all co-products, with an overall N-P_2O_5 ratio of around 2-1, after neutralization of phosphoric acid with ammonia and conversion of calcium nitrate to ammonium nitrate. Frequently the overall N-P_2O_5 ratio is 28-14, but this depends on the chemical analysis of the phosphate rock used. If the calcium nitrate produced in the initial digestion is utilized as calcium nitrate, instead of being converted to ammonium nitrate, then the overall N-P_2O_5 ratio will be around 1.1-1.

Since the overall N-P_2O_5 ratio of fertilizer consumption in many countries is around 2-1, nitrophosphate processes do fit the N-P_2O_5 consumption ratio of these countries, even though a single product with the composition 28-14-0 is not used very widely. It would probably be better practice to operate a nitrophosphate plant to produce a 24-24 primary product plus ammonium nitrate (34-0-0) or calcium nitrate (15.5-0-0) as a secondary product. Potash can, of course, be added to give a 17-17-17 primary product. In the phosphoric acid extraction process it is possible to produce 26-26-0 or 18-18-18 primary products.

In comparing the economics of two competitive processes there are two approaches which may be used:

1. Compare the two processes producing exactly (or approximately) the same product.

2. Compare the two processes producing the same primary product but different secondary products (or no secondary product).

In using the second approach there is the problem of selecting a price or value for the secondary product or products which will be agreed to by all persons to whom the comparison is of interest. This is very difficult to do.

Therefore this paper uses the first approach of comparing several processes producing exactly (or approximately) the same product. Four processes are compared, all producing 28-14-0 as the sole product:

1. Calcium nitrate crystallization process

2. Phosphoric acid extraction process

3. Calcium sulphate precipitation process (also called ammonium sulphate recycle process)

4. Sulphur-based process via sulphuric acid and phosphoric acid to produce ammonium phosphate plus the addition of enough nitric acid and additional ammonia to make a 28-14-0 product.

Admittedly probably no one would elect to make 28-14-0 by the last-mentioned process, but it could be made that way, and it does result in a product nearly identical with the 28-14-0 product made by the three nitrophosphate processes.

Figure 1 shows simplified flow sheets of the four processes and Table I shows the material and energy inputs per ton of 28-14-0. Table I indicates that the material and energy inputs of all four processes are approximately the same, except for sulphur. The sulphur-based process, of course, has a sulphur input which the other three processes do not have. The calcium nitrate crystallisation process uses about double the amount of electricity as the other three processes because of the cooling load. The calcium sulphate precipitation process uses more steam because of the greater evaporation load. Also, the calcium sulphate process has a small gypsum makeup because of ammonium sulphate losses in the calcium carbonate filter cake. But otherwise the inputs are nearly the same for all processes.

Table II gives the comparative production costs per ton of 28-14-0. With sulphur at $10/ton all four production costs come out very close, within a range of $29.25 to $30.35 per ton. According to these figures the phosphoric acid extraction process might have a slight edge, but the difference is probably less than the error of estimation and also this process has not yet been tested in a full-scale plant.

Production costs based on capital investment have been estimated at 30% of investment per year as detailed in Table III. The 30% per year includes operating labour and plant supervision at 2% per year which is as good an estimate of labour cost as a detailed analysis of numbers of personnel multiplied by their wage rates.

Labour and supervision is a minor cost in any event.

Costs based on capital investment are, of course, a major factor in the production cost calculation amounting to about 15% of total production cost in all four cases. Capital investment estimates are very difficult to obtain, particularly for a specific plant which has probably never been built anywhere. Estimates were obtained from a number of well-known engineering firms for plants based on the calcium nitrate crystallization, calcium sulphate precipitation and sulphur-based processes. The estimates for a plant producing 1430 T/D of 28-14-0 varied from $7 million to $10 million. Since there was no firm basis for assuming any significant differential among the processes, a figure of $7.5 million was selected for all four processes.

The figure of $7.5 million is consistent with capital cost estimates for smaller plants presented in papers at this Symposium by Chemoprojekt/Bamag (calcium nitrate crystallization) and by Typpi Oy (phosphoric acid extraction). It might be argued that the sulphur-based process should be assigned a smaller capital investment cost than the other three processes since it is a somewhat simpler process and does not require as much stainless steel equipment as the processes using nitric acid digestion of phosphate rock. However, if the sulphur-based plant is taken as $6.5 million it reduces the production cost by only $0.64 per ton, from $30.10 to $29.46 per ton (with sulphur at $10 per ton).

As another approach, the relative capital costs may be estimated roughly by comparing the major pieces of equipment required. Table IV lists the principal pieces of equipment required by each process and looking at these equipment lists there isn't much to choose among the four processes. Possibly the sulphur-based process might be a somewhat lower capital cost than the other three. The list of equipment for the sulphur-based plant is shorter, but the sulphuric acid and phosphoric acid plants are relatively expensive.

The reader should please note that in this comparison all four processes use the same amount of nitric acid so that the cost of a nitric acid plant is not included in the capital cost of any of the processes. It is assumed that all four plants producing the 28-14-0 product would be attached to an ammonia/nitric acid plant.

Figure 2 compares the production costs of the four processes as a function of the price of sulphur. In the three nitrophosphate processes the production costs are, of course, independent of the price of sulphur. But the production cost of the sulphur-based process is a linear function of the price of sulphur. Neglecting the relatively minor differences among the production costs of the three nitrophosphate processes, it appears that nitrophosphate processes are economically competitive with sulphur-based processes when sulphur is around $10 per ton delivered at the plant site. While the price of sulphur is much lower in 1971 than it was in 1968, yet there are very few locations in the world where sulphur can be delivered to a plant site for $10 per ton.

The foregoing comparison is obviously an artificial approach since it is unlikely that anyone would build a plant to make a 28-14-0 product via sulphuric and phosphoric acids, but yet the analysis gives a general basis for comparing the relative economics of nitrophosphate processes vs. sulphur-based processes. The decision to adopt or not to adopt a nitrophosphate process in a particular country will depend on whether the country can effectivel use the types of fertilizers produced by nitrophosphate processes.

The old question of water solubility of the phosphate component of fertilizers is no longer of significance since any degree of water solubility of phosphate, up to 100 percent water solubility, can be made by any of the new nitrophosphate processes developed during the past six years. However, it is questionable whether phosphate water solubility over 80 percent has any real merit, and several nitrophosphate projects during the past few years have deliberately selected 60 percent water solubility when they could have had 80 or 90 percent water solubility, but at higher cost.

Abbreviations

PR = Phosphate rock

CN = Calcium nitrate

CS = Calcium sulfate

CC = Calcium carbonate

NA = Nitric acid

SA = Sulfuric acid

PA = Phosphoric acid

AN = Ammonium nitrate

AS = Ammonium sulfate

MAP = Monoammonium phosphate

DAP = Diammonium phosphate

TAP = Triammonium phosphate

DCP = Dicalcium phosphate

TCP = Tricalcium phosphate

NP = Nitrophosphate

Table 1

Material and Energy Inputs per Ton of 28-14-0

	Calcium nitrate crystallization process*	Calcium sulphate precipitation process**	Phosphoric acid extraction process*	Sulphur-sulphuric acid-phosphoric acid process	Prices of Inputs
Phosphate rock, tons	.43	.43	.43	.43	$15/ton
Nitric acid, tons	.58	.58	.58	.58	$15/ton
Ammonia, tons	.20	.20	.20	.20	$35/ton
Sulphur, tons	--	--	--	.135	$10/ton
Gypsum, tons	--	.12	--	--	$ 5/ton
Steam, tons	.50	1.00	.50	--	$ 1/ton
Fuel oil, kg.	25	25	25	25	6¢/kg.
Electricity, kwh.	100	50	50	50	1¢/kwh.
Cooling water, cu.m.	30	30	30	30	1¢/cu.m.

* Calcium nitrate crystallization processes and phosphoric acid extraction processes operated with conversion of calcium nitrate to ammonium nitrate and re-injection of all ammonium nitrate into the main N-P process stream.

** Calcium sulphate precipitation process operated as "straight through" process with no offtake of AN or MAP.

@ Nitric acid produced in 600 MT/D plant with ammonia costed at $35/MT.

Table 11

Production Costs per Ton of 28-14-0

	Calcium nitrate crystallization process	Calcium sulphate precipitation process	Phosphoric acid extraction process	Sulphur-sulphuric acid-phosphoric acid process[@]	Prices of Inputs
Capital investment*	$7,500,000	$7,500,000	$7,500,000	$7,500,000	
Operating inputs**					
Phosphate rock***	$6.45	$6.45	$6.45	$6.45	$15/ton
Nitric acid	8.70	8.70	8.70	8.70	$15/ton
Ammonia	7.00	7.00	7.00	7.00	$35/ton
Sulphur	--	--	--	1.35	$10/ton
Gypsum	--	.60	--	--	$ 5/ton
Steam	.50	1.00	.50	--	$ 1/ton
Fuel oil	1.00	1.00	1.00	1.00	4¢/kg.
Electricity	1.00	.50	.50	.50	1¢/kwh.
Cooling water	.30	.30	.30	.30	1¢/cu.m.
	24.95	25.55	24.45	25.30	
Costs based on capital (30% of capital/year)	4.80	4.80	4.80	4.80	
	$29.75	$30.35	$29.25	$30.10	

* Plant size - 1430 T/D or 472,000 T/y of 28-14-0

** Carbon dioxide, process water, white spirit (CHP/Bamag process), solvent loss (Typpi Oy process) are all neglected because very small.

*** Phosphate rock - 34.4% P_2O_5

@ If capital investment of sulphur-based plant is assumed to be $6,500,000 (instead of $7,500,000), then costs based on capital would be reduced by $0.64 and total production cost would be reduced to $29.46.

Table III

Production Costs Based on Capital Investment

Operating labor + plant supervision	2%	of investment	per	year	
Maintenance labor + materials	5%	"	"	"	"
Plant overhead	2%	"	"	"	"
Taxes and insurance	3%	"	"	"	"
Interest on investment	8%	"	"	"	"
Depreciation	10%	"	"	"	"
Total	30%				

Table IV

Major Pieces of Equipment Required

Calcium nitrate crystallization process	Calcium sulphate precipitation process	Phosphoric acid extraction process	Sulphur-sulphuric acid-phosphoric acid process
Digester	Digester	Digester	Sulphuric acid plant
Crystallizer (for CN)	Precipitater (for CS)	Extracter (for PA)	Digester (for PA)
Filter (for CN)*	Filter (for CS)	Neutralizer	Filter (for CS)
Ammonio-carbonater	Ammonio-carbonater	Separater	Neutralizer
Filter (for CC)	Filter (for CC)	Ammonio-carbonater	Evaporater
Neutralizer	Neutralizer	Filter (for CC)	Granulater**
Evaporater	Evaporater	Evaporator	
Granulater**	Granulater**	Granulater**	

*Centrifuge can be used in calcium nitrate separation

**Prilling tower may be used instead of granulater

Figure 1

Simplified Flow Sheets of Four Processes For Making 28-14-0

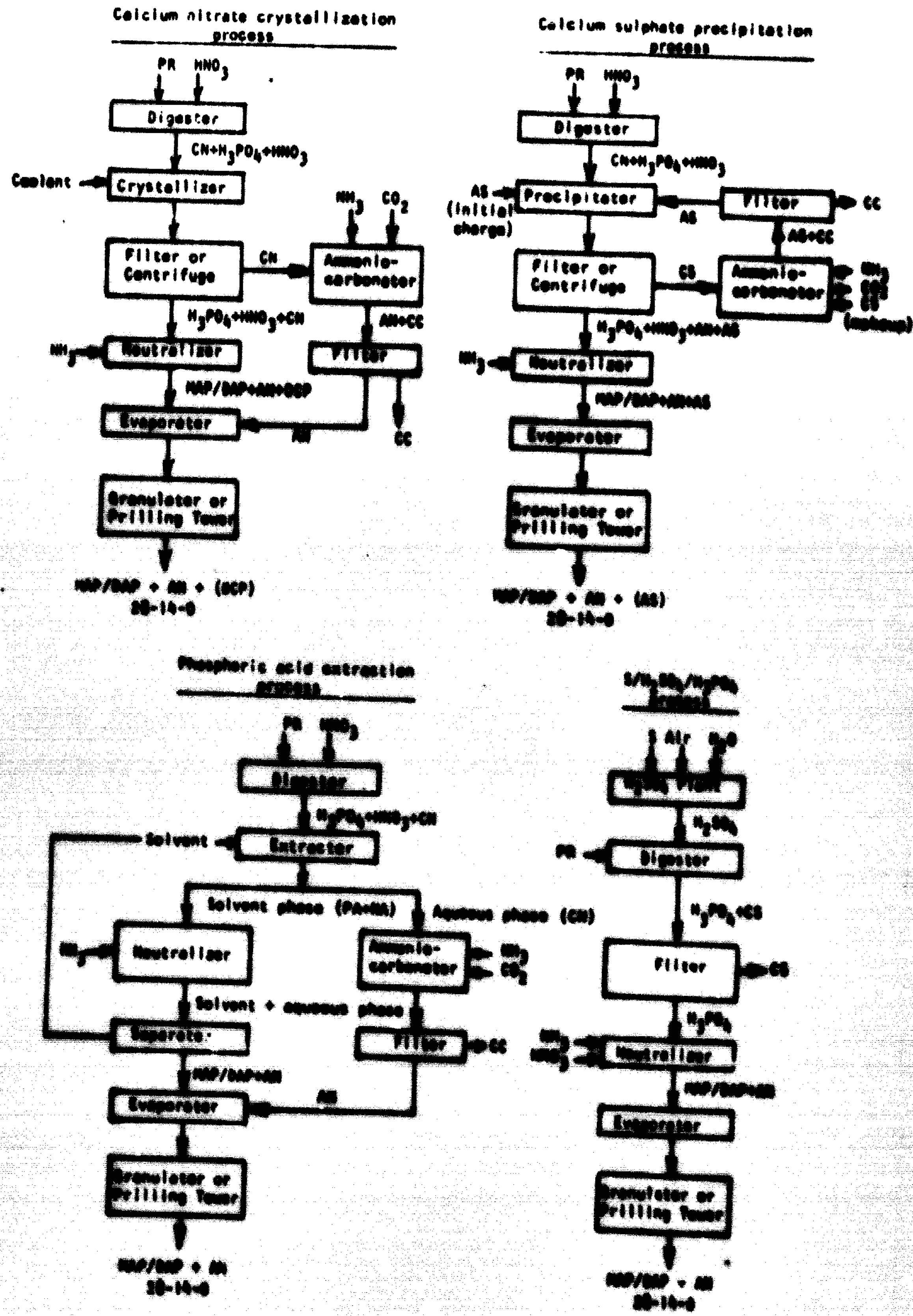
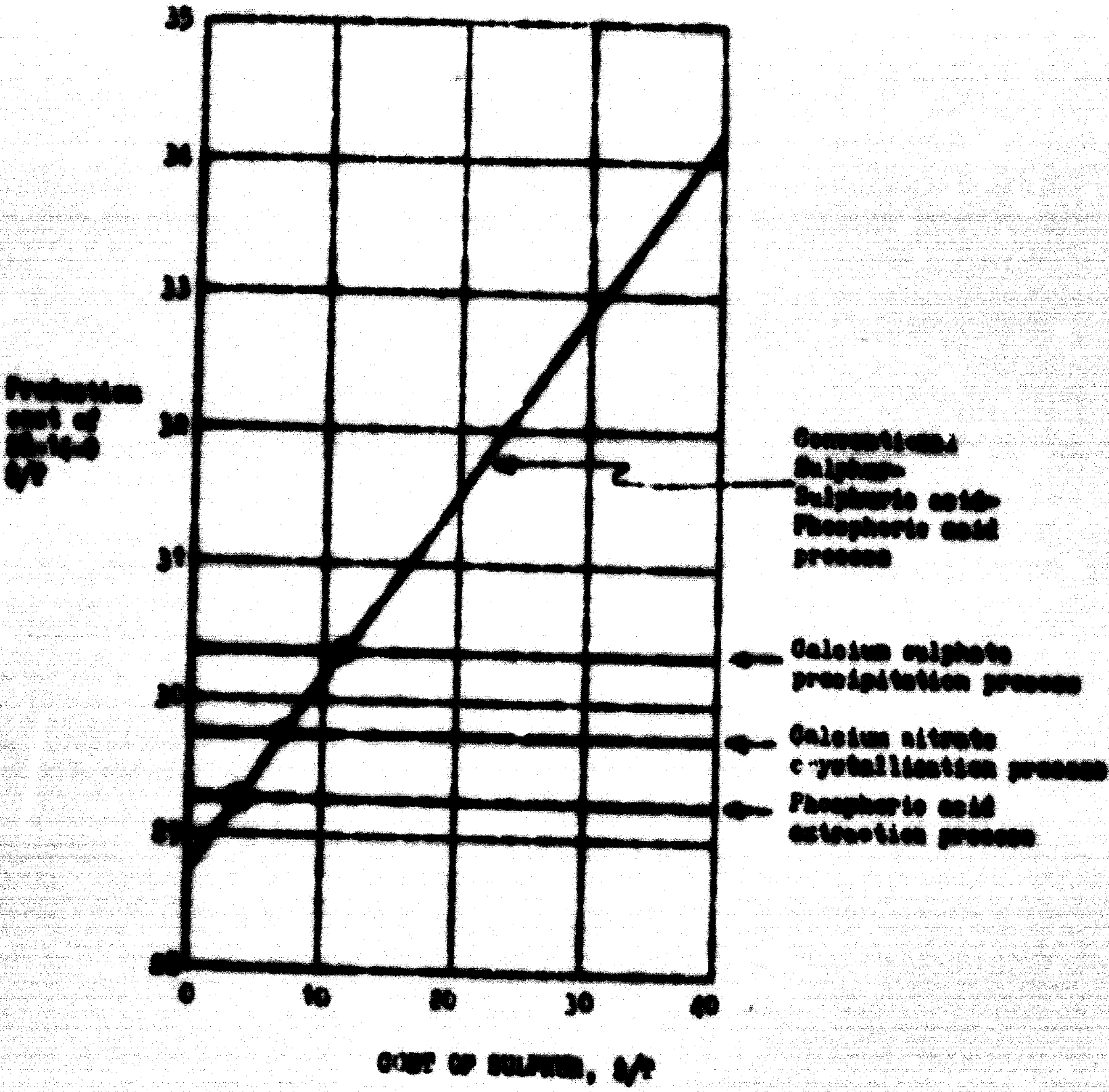


Figure 2

COST OF PRODUCTION OF 28-14-0



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