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EVALUATION OF COMPLEX FERTILIZER MANUFACTURE BASED ON SYSTEMATIC ENERGY ACCOUNTING

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SYNOPSIS

The evaluation makes use of a method for keeping account of total energy consumption required to produce complex fertilizer by the two main process routes, viz. :

I. A sulphur based NPK process
II. The Norsk Hydro nitrophosphate process

Comparable battery limits for the production complexes are specified, and the energy contents in the various raw materials and energy carriers are defined.

The result of this overall analysis shows a significant difference in favour of the Norsk Hydro nitrophosphate process.

An attempt to forecast the influence of higher energy costs on the utilization of the two process routes is indicated.

1) INTRODUCTION

The most common way to compare different processes is to inspect figures for investments and operating costs. The basic method for this comparison is to use the monetary unit and the economic system in the respective countries, and the unit price of the various cost factors. The weakness of this comparison is the fluctuation of capital interest and unit prices which both reflect the market conditions. Thus an economical survey made in 1980 may have less significance in 1990.

The last few decades have clearly demonstrated that energy is representing a bigger and bigger share of the total production cost. It should therefore be reasonable to believe that those production processes which require the least total energy consumption should have the strongest position in the future.

Consequently an accounting system which may determine the total energy consumption for chemical processes should be acknowledged as a valuable indicator of future technological trends.

With this in mind we are pleased to present figures of the energy consumption for manufacturing complex fertilizer by the Norsk Hydro nitrophosphate process compared with the use of a sulphur based route.

2) SYSTEM FOR KEEPING ACCOUNT OF TOTAL ENERGY FLOWS

In order to have a quantitative measure for the efficiency of the utilization of energy within a production unit or within an industrial complex, it is required to apply a uniform accounting system.

The main principle in a system used by Norsk Hydro today is that a production unit or a plant will receive raw materials energies and utilities each containing a certain defined unit energy.

For most raw materials, this energy is related to the energy required to produce and transport the raw material to the production site. The unit energy for oil, gases or other materials with well defined combustion reactions is generally set equivalent to their combustion energy. As an example, natural gas, which is used for ammonia production, is given a unit energy equal to the combustion energy. Furthermore, electric power is as basis assumed to be generated in a thermal power station with a total efficiency of 33.3% giving a unit energy of 10.8 GJ/MWh.

A list of unit energies is presented in Appendix 1.

Sulphur is an important element in these energy balances. It has normally been acknowledged as a raw material, but it could seem difficult to establish a general basis for its unit energy (1), because of different production conditions.

The energy efficiency within a sulphur based fertilizer complex is clearly connected to the utilization of the combustion energy from sulphur for production of electricity and/or steam.

Taking this into consideration, we have found it reasonable to use 16.5 GJ/t S as the best estimate for the unit energy as it represents the energy from the overall combustion reaction :

$$S + 1\ 1/2\ O_2 + H_2O \longrightarrow H_2SO_4$$

This concept has been the basis for our calculation of the gross specific energy consumptions for alternative production routes.

Gross specific energy consumption is defined as the total energy supplied to a production unit in the form of raw materials or other forms of energy (steam, electric power, etc.) devided by the production rate.

It should be pointed out that the comparison of processes involving otherwise identical raw materials is not much sensitive to inaccuracies in the value of their unit energies.

3) DEFINITION OF TECHNOLOGIES AND OVERALL BATTERY LIMITS

3.1 Norsk Hydro nitrophosphate process

The Norsk Hydro nitrophosphate process should be well known through presentations and publications made during the last 10 years (2,3), but nevertheless, a short description is included below, and a simplified flowsheet is shown in fig. 1. Raw materials for this process are phosphate rock, nitric acid, ammonia, potassium salt and finally carbon dioxide for the conversion of by-product calcium nitrate. The process consists of the following main process steps :

- Digestion of phosphate rock
- Crystallization of calcium nitrate

- Filtering of calcium nitrate
- Neutralization of the mother liquor
- Evaporation and prilling

Further, as previously mentioned, the by-product calcium nitrate is normally converted into ammonium nitrate and calcium carbonate through reaction with carbon dioxide and ammonia. The ammonium nitrate by-product solution can either be returned to the neutralization step of the main process in order to adjust the $N:P_2O_5$ ratio of the final product, or it can be processed into ammonium nitrate fertilizer.

Product formulations with $N : P_2O_5$ ratios from 0.7 to 2 can be obtained by manipulation of the internal product flows within the normal range of operation, and other formulations are obtainable through addition of phosphoric acid or ammonium nitrate from an external source. The final product reaches a P_2O_5 water solubility of 80-85%. Potassium salts and micronutrients are added in the mixer prior to prilling.

The process will, for a 1-1-1 product, typically give about 3.4 t ammonium nitrate by-product per t P_2O_5. It is normally produced as a pan granulated solid product containing 34.5% N, but also other N contents can be obtained.

The specific consumption figures for production of prilled 1-1-1 NPK plus pan granulated ammonium nitrate are defined in Appendix 2 and are given per t P_2O_5.

3.2. Sulphur based complex fertilizer production

We have presented in figure 3 a block diagram of the sulphuric acid alternative for production of complex fertilizer, 1-1-1 composition,containing ammonium nitrate. As this route could give a slightly higher product nutrients level, we have compensated this by relating consumption figures to 1 t P_2O_5 in the final product.

Different sources of sulphur and different process routes can be selected for the first step of the sulphur based alternative, i.e. for the sulphuric acid unit.

In this comparison we have used elementary sulphur as inlet feed stock and a double absorption system as reference. Reflected in the utility figures is a design with electric drives of all machinery in the basic plant and export of steam. As explained later, this concept is regarded as advantageous for the total sulphur based complex (4).

As reference for the phosphoric acid process, we have chosen a standard dihydrate process alternative. The acid is typically produced as a regular 54% P_2O_5-grade

For complex fertilizer production we have selected a granulation process with separate neutralization with ammonia of phosphoric and nitric acid. The ammonium phosphate slurry from the neutralization contains typically 12% water whereas the ammonium nitrate solution from the nitric acid neutralizer is concentrated by evaporation to 98% before mixing (5).

The resulting slurry, together with potassium salt, is fed to a granulator, and then dried in a conventional drier. The finished product is subsequently screened, cooled and stored whereas fines and crushed oversize are returned to the granulator as part of the recycle material.

A production unit for solid ammonium nitrate with its defined consumption figures has been included in the complex.

Specific consumption figures are listed in Appendix 3.

3.3. Definition of overall battery limits

Then, in order to settle comparable and well defined boundary limits for th complexes, production facilities for ammonia and nitric acid are also included. The two alternatives are presented in the block diagrams in figures 2 and 3.

The ammonia unit will be similar for the alternatives and the choice of process route will not influence the overall result. The basic consumption figures for the plants are presented in Appendix 4.

A standard dual medium-high-pressure process has been selected for the nitric acid unit. The surplus of steam from this process unit is moderate as the main compressor is typically assumed to be steam-driven. The consumption figures are also given in Appendix 4.

4) BASIS OF THE ANALYSIS

As specified above, comparable production complexes are defined. The complexes, which are visualized by block diagrams in figures 2 and 3, contain all necessary production units upstream for receiving basic raw materials and producing complex fertilizer of a specific quality (product grade 1:1:1) and solid ammonium nitrate as final products.

The amount of products and by-products are the same in both cases namely 2120 t per day NPK, 1-1-1 and 1190 t per day ammonium nitrate (34.5% N).

As an alternative route within the sulphur based complex we have also examined a urea ammonium phosphate complex (consumption figures in Appendix 5). The NPK production is the same and an amount of urea, equivalent in nitrogen to the by-product of ammonium nitrate for the nitrophosphate process, is included to balance the raw material requirements.

Each unit in the complexes has its own defined consumption figures of raw materials and utilities which have been used to obtain the requirements per 1 t P_2O_5 in the final product.

Co-generation units have been incorporated in the production complexes when there is a simultaneous need for steam and power. The following definition of co-generation has been used : "coincident generation of steam and power - electrical or mechanical - or the recovery of process energy for power production". The exploitation of heat and power has been set to 47% and 30% respectively of the total input energy although small interactions in these figures might appear for different steam levels. The figures reflect the conditions with gas based co-generation systems (6).

5) EVALUATION OF THE RESULTS

5.1. General

The gross energy consumption for the alternative complexes is presented in Appendix 6.

The major energy consumer in both process routes is the ammonia plant, accounting for more than 60% of gross specific energy consumption.

When examining the raw materials - excluding sulphur in this context - there are slight differences but notably in favour of the nitrophosphate process due to better P_2O_5 recovery.

This clearly demonstrates the importance of being able to utilize the exothermic oxidation reactions for steam production. In this respect the contribution by the nitric acid unit is also significant.

5.2. Consumption of electric power

A closer look at the different energy carriers might be of interest for the understanding and the evaluation of the result.

In the nitrophosphate complex the consumption figures of electric power and steam show excellent conditions for incorporation of a co-generation unit as shown in figure 4.

Further examination shows that the power consumption may be lower than generally expected. The label "deep-cooling process" could lead to the assumption that large quantities of power is needed for the refrigeration unit.

The survey in Appendix 7 reveals that the cooling unit has a relatively moderate requirement. The reason is that ammonia, evaporated for use in the neutralization and conversion section, provide some 75% of the required cooling load for the crystallization of calcium nitrate tetrahydrate.

Looking at the power consumption in the sulphur-based complex, the phosphoric acid unit and the NPK granulation unit are the main consumers. In a phosphoric acid unit rock grinding and the reaction section require typically over 60% of total power with rock grinding alone taking around 40% (8).

In total, omission of grinding plus the high rate of dissolution when using nitric acid instead of phosphoric acid results in a power consumption for the nitrophosphate alternative of less than 10% of the corresponding consumption in the phosphoric acid plant.

The main consumer of electric power in the sulphur route would be the NPK granulation section. The consumption in this section, expressed as energy per tonne of NPK product, could be 38-40 kWh with a relatively small part in the wet section and the main part in the granulation loop itself (5). A typical recycle ratio would be 3:1 with substantial power requirements in equipment for material handling like the drier, crusher, elevator, etc.

Comparing these figures with the NPK prilling process, energy savings are clearly demonstrated in the latter. With its low recycle ratio, the electric power requirement easily drops to less than half of the above mentioned figure.

5.3 Steam consumption

Steam consumption in the nitrophosphate process is dominated by evaporation of ammonium nitrate solution (60%) from the conversion plant and of neutralized NP-liquid (Appendix 8).

For the ammonium nitrate solution, double effect evaporation has already been taken into use to save energy.

The evaporation of NP liquid represents the second largest consumer. Any multi-effect evaporation must be excluded here because of the difficult characteristics of the melt. Compared to the energy efficiency in a drier, the evaporation of water from a melt is a very energy-efficient process. The build-ups of deposits on the heated surfaces are moderate and fluidity is maintained with a rather low proportion of ammonium nitrate and phosphate compared to the total raw materials. Slight improvement in steam consumption may be obtained by utilization of hot condensate as process water.

A large available energy source is the vapour evolved from the neutralization. Here, the heat of reaction from neutralizing phosphoric acid and free nitric acid evaporates substantial amount of water. Amounting to about 1 t per 1 t P_2O_5, its energy content is under evaluation for several alternative uses. A main obstacle is, however, a high content of non-condensable gases (air) in the vapour with a resulting severe effect on the rate of condensation.

The steam consumption in the sulphur route is principally dominated by the process of concentration of phosphoric acid from 28% to 54% (about 70% of the total requirement). The remaining 30% are linked to the production of ammonium nitrate as concentrated solution or as solid product.

For phosphoric acid concentration the introduction of a concept with multi-effect evaporation with a potential steam saving of 40% does not seem to have reached beyond the point of interest.

Another feature could also be incorporated into future planning according to articles in this field (8). By utilizing hot water from sulphuric acid coolers the concentration could be raised to 40% P_2O_5 and thereby reducing the consumption of low pressure steam by some 60%. The savings do not come free of charge, it will require increased investment, increased power consumption, etc., which could be a too large burden even on this substantial incentive.

The granulation section could use many process alternatives (slurry granulation, solid MAP, co-neutralization and evaporation, etc.). The one chosen in this context, the mixed liquor process, requires the lowest consumption of medium pressure steam and the highest consumption of 2 bar steam of the mentioned alternatives (5). For the complex as a whole, this leaves a maximum amount of steam to be utilized for power production.

As a basis for the ammonium nitrate technology we have selected a pressure neutralization with reactor steam being utilized for evaporation up to 95% solution. The surplus heat of reaction is taken out as low pressure steam in a separate boiler normally located in a circulating loop over the reactor.

In the wide range of ammonium nitrate neutralizer technology it is difficult to select one as representative. The process described has been in successful operation for several years and is regarded as a good example for energy recovery (9).

Many would, however, be in favor of the simpler atmospheric neutralizer installation which would in practice lead to a higher consumption of medium pressure steam.

5.4. Energy accounting scheme

5.4.1. Nitrophosphate process

By examining the different units in the nitrophosphate complex a need of energy supplied in the form of steam is clearly shown.

The two steam generating units are the ammonia and the nitric acid plants. These plants are normally designed for utilizing the steam for mechanical drives within the units. In these cases a centralized co-generation unit and/or steam turbine have been considered in order to cover wholly or partly the requirements of electric power within the complex.

The scheme we present in figures 4 and 5 is thus only meant to highlight a few aspects and not represent any optimum situation.

The complex is worked out as a theoretically self-supplied unit also with respect to electricity and with gas as the only primary fuel. The self-supply of electricity illustrates well the possibilities of a co-generation system. In the scheme the co-generation and the double extraction condensing turbine are presented as separate physical units. In an actual installation the power generating units could be integrated by increasing the installation of common mechanical equipment within the ammonia plant.

A main consideration in any scheme would be the need to cover fluctuations in both steam and electrical energy consumption. While the ammonia and nitric acid units maintain a rather stable ratio between steam and electric power, the NPK unit shows a more complex operating pattern. With ample buffer volumes a very high regularity is proven, but the steam requirement is particularly dominated by a few large consumers of medium pressure steam for evaporation purposes. Shut-downs in these sections will therefore greatly influence the generation of electric power.

By examining the ratio between steam and electric power it seems convenient to use an additional gas fired boiler. This last unit can quickly be adjusted to the fluctuating steam needs. At reduced steam load, electricity production can be maintained in the co-generator system and more of the high pressure steam be expanded down the condensing pressure. Electricity export may even be economically interesting for a local power board, but will depend upon the amount and the length of the delivery period. The boiler must, however, be designed to be able to master the start-up conditions when steam and power requirements are far from normal.

Case B relies on electric power import from the local board and with internal steam supply only.

This modification adds another 2.86 GJ/t P_2O_5 to the energy requirement.

Thus the co-generation unit in scheme A could easily be justified with an expected pay-back period of 1-2 years.

5.4.2. Sulphur based route

The energy-efficiency of the total sulphur-based complex is characterized by the total steam surplus and by an important consumption on the 2 bar level. The conditions for generating steam at a high pressure and to place an efficient co-generation unit within the production complex should be excellent.

In this case the sulphuric acid unit should produce steam at an economical and justifiable pressure. In practice the surplus steam from nitric acid unit is integrated with the steam from sulphuric acid unit before entering a common co-generation system.

For this installation a double automatic extraction, condensing turbine may be interesting. These units should give flexibility to respond automatically to variations in steam demand besides the control of power generation.

5.4.3. Urea ammonium phosphate alternative

We also found it interesting to look at the combination of sulphur-based ammonium phosphate and urea for production of NPK.

The complex is presented in figure 7. It has as basis the same NPK production and an amount of urea equivalent to the nitrogen by-product in the nitrophosphate process.

As seen by the analysis, the energy balance is not in favour of such a combination. The higher energy consumption is primarily caused by a major requirement of high pressure steam for the urea-process, which reduces the electricity production from co-generation.

This is a rather rough evaluation of the alternative, but the difference towards the other two processes seems quite significant. An improvement of this alternative by optimal design and updated process information may reduce this difference.

5.5. The co-generation concept

The schemes presented both on the nitrophosphate and the sulphur-based route may seem a somewhat scientific approach to maximize the energy utilization.

There could be atrong objections to introduce additional complexity by common steam and power generating systems. This being particularly so if only a few days' loss of output due to breakdowns can more than eliminate the anticipated savings in energy.

On the other hand, there seems to be strong economic incentives to seriously consider such installations, and with the overall technical experience today with such power generating systems, this should not be a risky step forward.

6) CONCLUSION AND FUTURE TRENDS IN FERTILIZER PRODUCTION

The method for keeping account of the total energy consumption has been used for some time by Norsk Hydro. Analysing the production of complex fertilizers was an obvious step due to our interest in this field.

The final results of this work are shown in detail in Appendix 6. For an overall comparison it is mainly the bottom line of each set-up that require attention :

I A Norsk Hydro Nitrophosphate Complex Scheme A (figure 4) :	110.6 GJ/t P_2O_5
I B Norsk Hydro nitrophosphate complex Scheme B (figure 5) :	112.9 GJ/t P_2O_5
II A Sulphur-based NPK Complex (figure 6) :	121.6 GJ/t P_2O_5
II B Sulphur-based NPK Complex with Urea-Ammonium Phosphate (figure 7)	130.5 GJ/t P_2O_5

The situation in this field is clearly demonstrated by the fact that the Norsk Hydro nitrophosphate process needs less total energy for production of complex fertilizer when taking into account all supplies of raw materials, electric power and utilities.

The higher total energy consumption accumulated per unit product via the sulphur-based route states the fact that sulphur must be obtained at a low price (low energy cost) to justify that alternative.

In contrast, sulphur, as an energy carrier, has today a rather high cost compared to other sources. With an expected trend of overall shortage also in the near future any major change in that cost situation seems unlikely.

With a further development of the general technological level and with higher perfection in all process steps, we feel that the specific unit energy in the product will in the future get more attention as an indicator of competitive production technology.

7) NOTATIONS

The calculation and the presentation have been worked out with SI-units.

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9. FIGURES

1. Norsk Hydro NPK-process, Block Diagram

2. NPK-Complex with Norsk Hydro Nitrophosphate process

3. Sulphur-Based NPK-Complex

4. NPK-Complex with Norsk Hydro Nitrophosphate Process energy Accounting Scheme A.

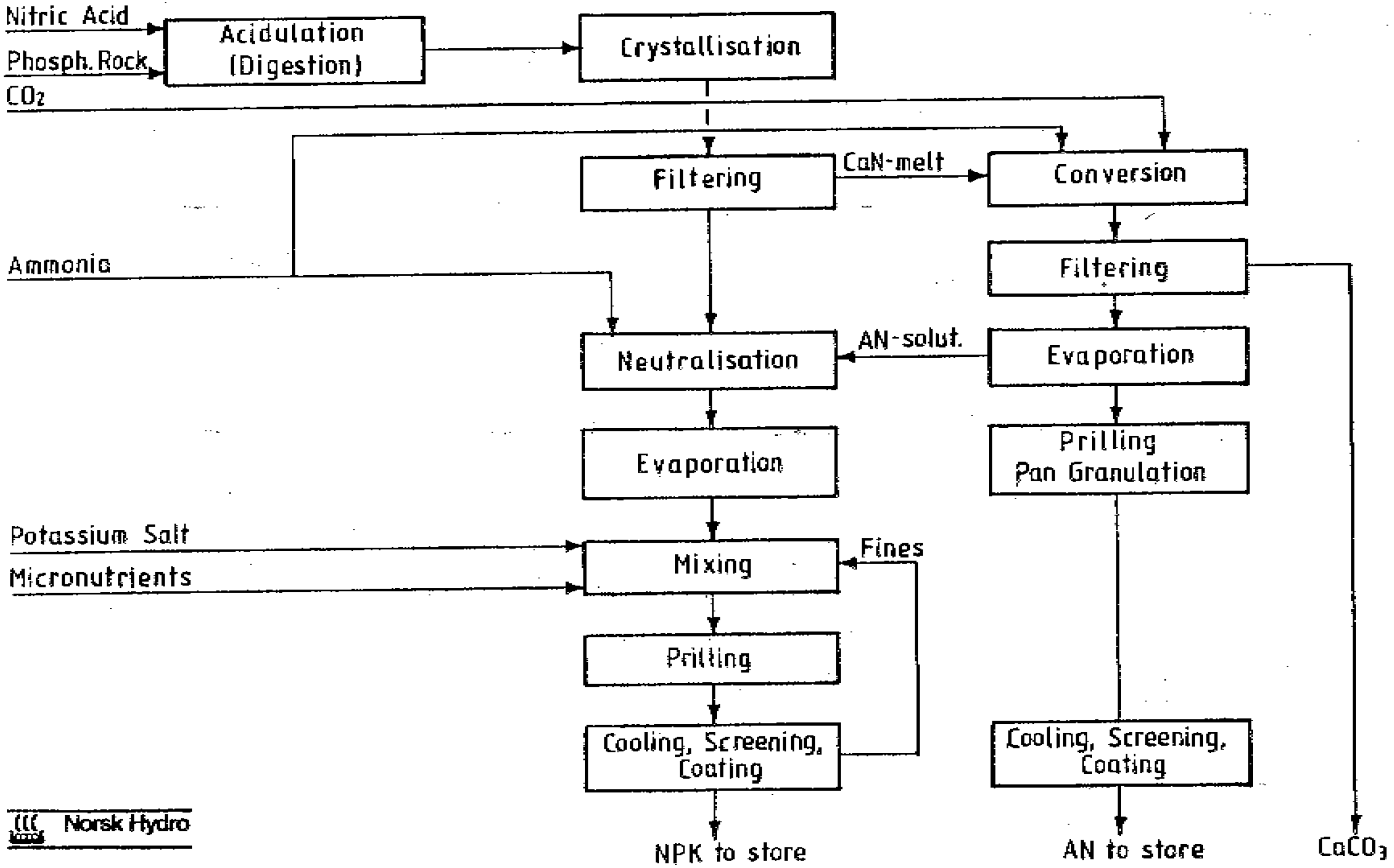
5. NPK-Complex with Norsk Hydro Nitrophosphate process Energy Accounting Scheme B.

6. Sulphur-Based NPK-Complex Energy Accounting Scheme.

7. Sulphur-Based NPK-Complex with UREA-Ammonium Phosphate Energy Accounting Scheme.

Figure 1

Norsk Hydro NPK-process, Block Diagram.



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NPK-COMPLEX with NORSK HYDRO
Nitrophosphate Process

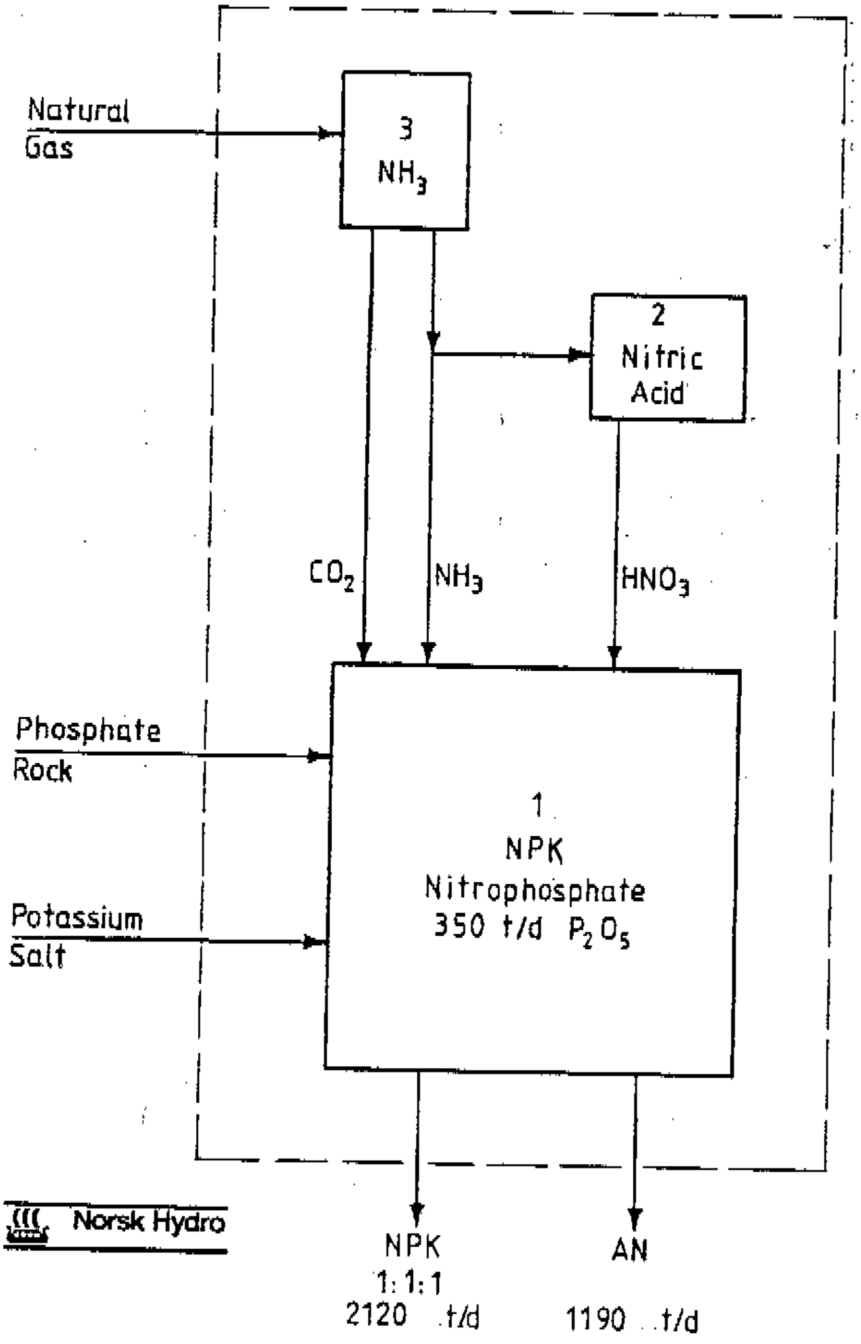

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Figure 2

SULPHUR-Based NPK-COMPLEX

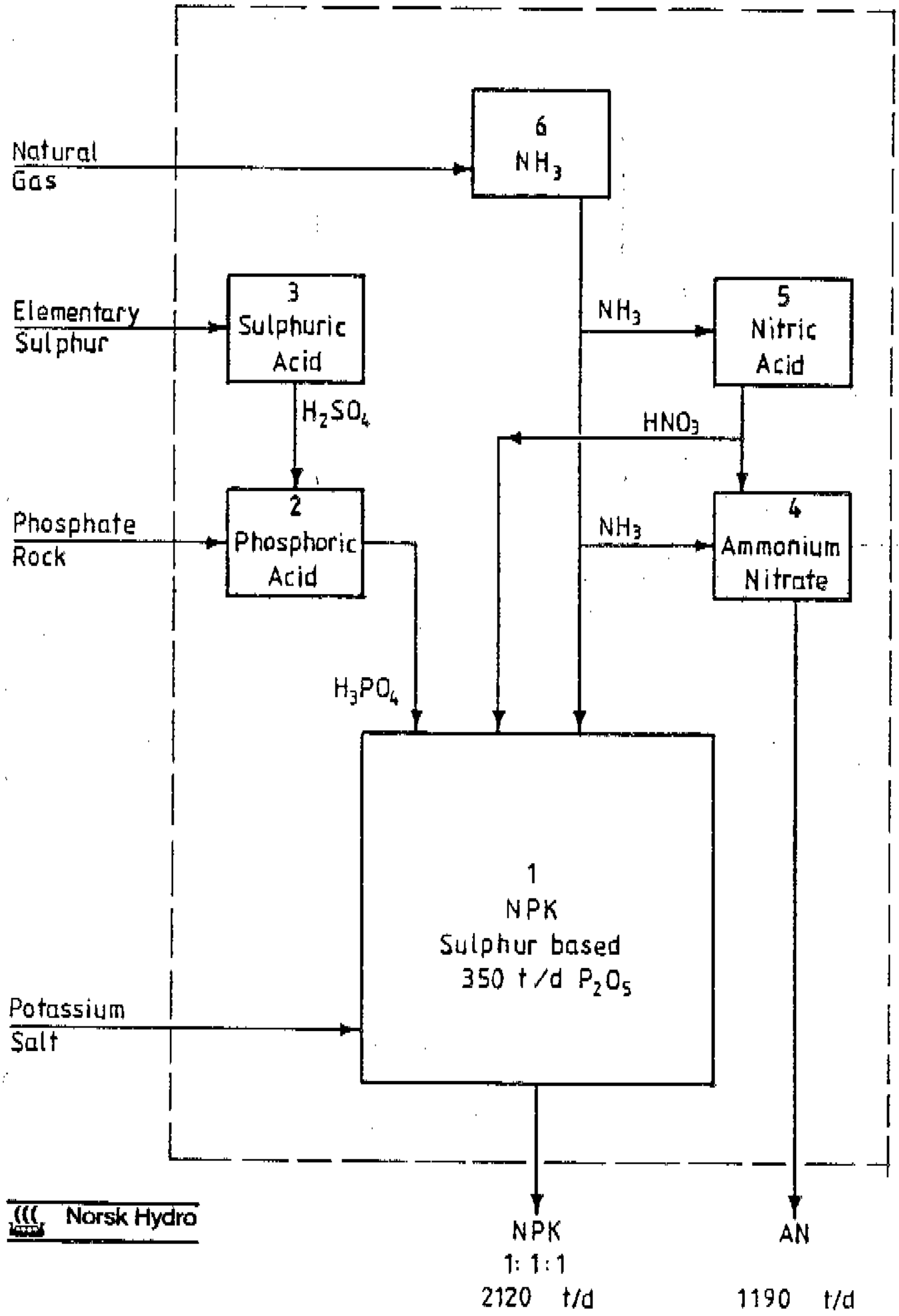

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Figure 3

NPK-COMPLEX with NORSK HYDRO
Nitrophosphate Process
Energy Accounting Scheme A
Figures are per 1 t P_2O_5

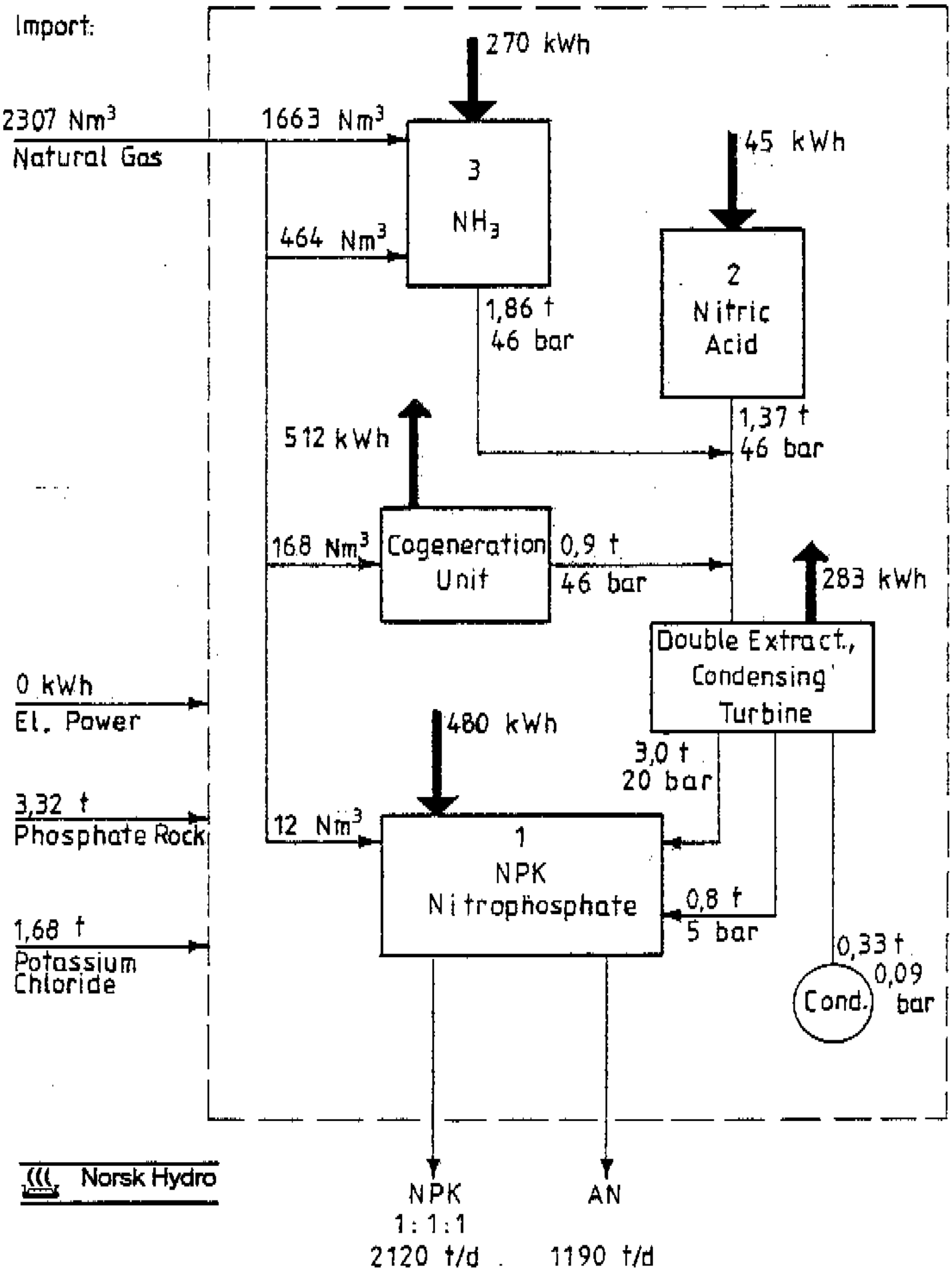

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figure 4

NPK-COMPLEX with NORSK HYDRO

Nitrophosphate Process

Energy Accounting Scheme B

Figures are per 1 t P_2O_5

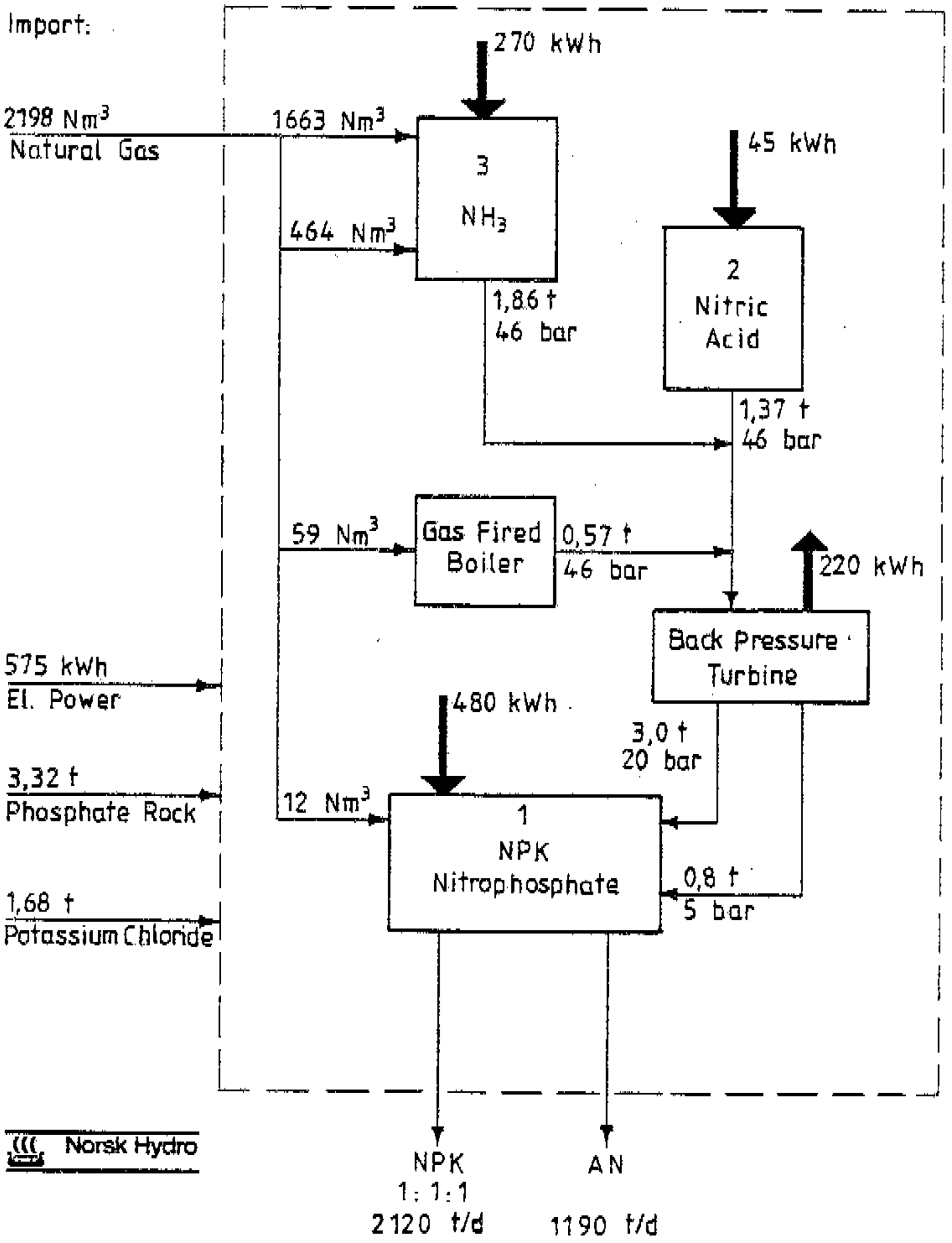

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Figure 5

SULPHUR-Based NPK-COMPLEX
Energy Accounting Scheme
Figures are per 1 t P_2O_5

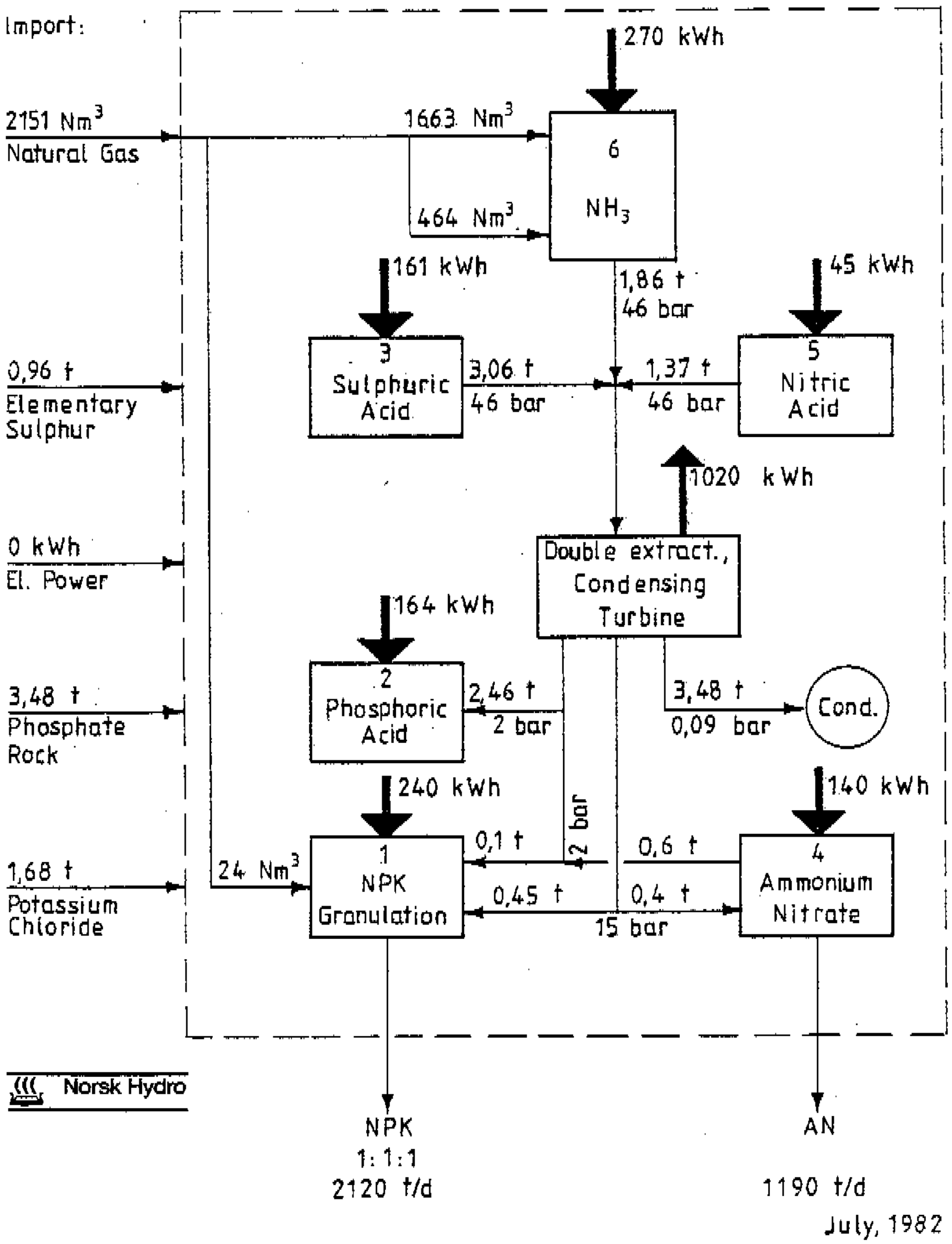

Figure 6

SULPHUR-Based NPK-COMPLEX
with UREA-AMMONIOM PHOSPHATE
Energy Accounting Scheme
Figures are per 1 t P_2O_5

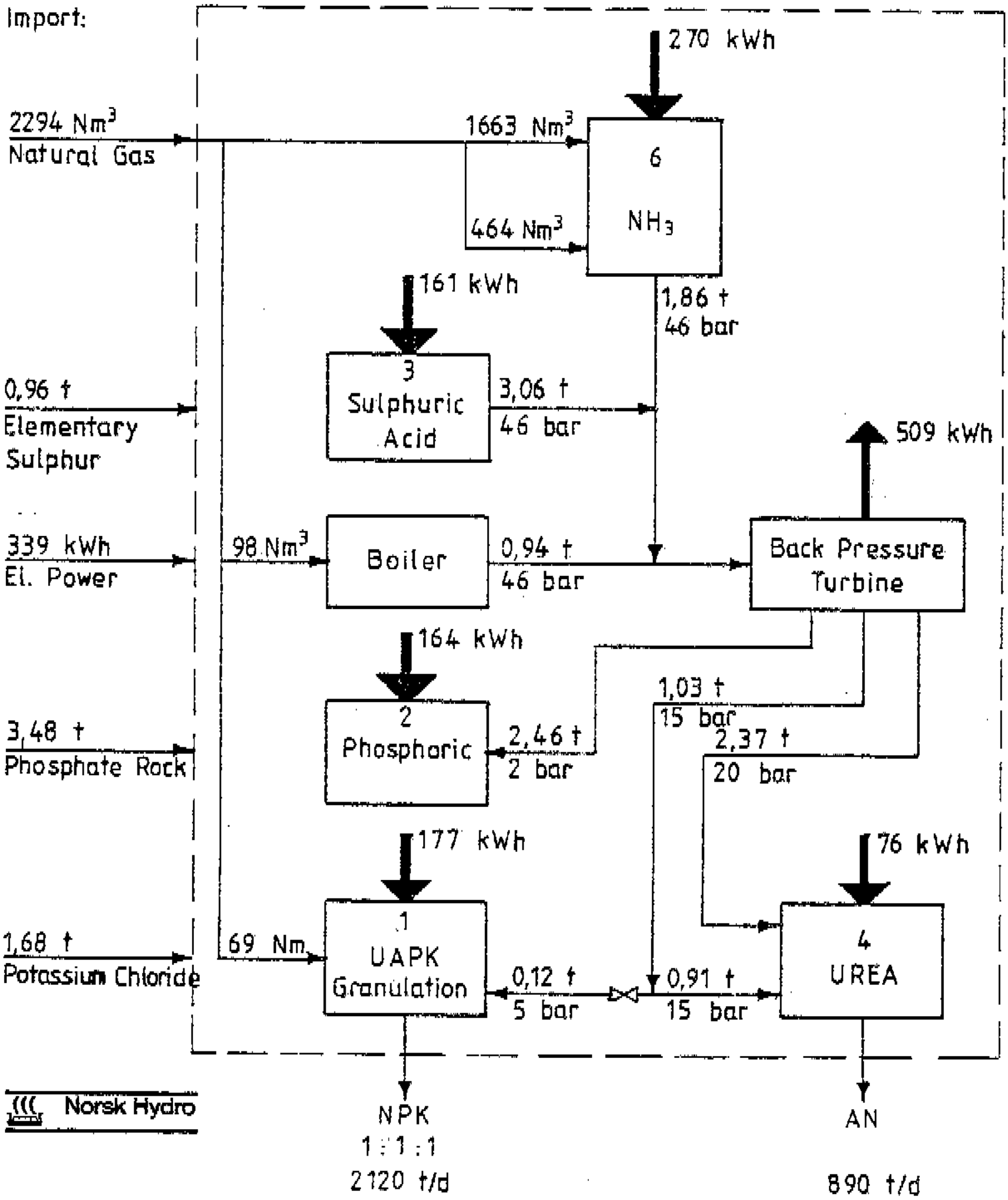

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Figure 7

10. APPENDICES

1. Basic Unit Energies
2. Consumption Figures for Norsk Hydro Nitrophosphate and Pan Granulation Process.
3. Consumption Figures for the Sulphur-Based Production.
4. Consumption Figures for Ammonia and Nitric Acid Plant.
5. Typical Consumption Figures for UREA Ammonium Phosphate Production.
6. Gross Energy Consumption of Complexes
7. Electric Power Consumption in the Nitrophosphate Plant.
8. Steam Consumption in the Nitrophosphate Process

Appendix 1

Basic Unit Energies

(1 GJ = 10^9 joule = 238844 Kcal = 277,78 kWh)

Phosphate rock*	5	GJ/t
Potassium chloride*	5.6	GJ/t
Electric power (η_T = 0,333)	10.8	GJ/MWh
Natural gas, per 1000 Nm^3	36.56	GJ
Sulphur, elementary	16.5	GJ/t

The unit energies marked with an asteric originate from an energy matrix published by the Energy Research Group, University of Illinois.

Appendix 2

Consumption Figures for Norsk Hydro Nitrophosphate and Pan Granulation Process

The data refers to a complex fertilizer production of 2120 t/d of 1-1-1 grade plus 1190 t/d ammonium nitrate (34.5% N) fertilizer.

Figures per 1 t P_2O_5 in 1-1-1 NPK-grade:

Phosphate rock (30.4% P_2O_5)	3.32	t
Nitric acid (as 100%)	4.43	t
Ammonia	1.44	t
Potassium chloride	1.68	t
Carbon dioxide	1.21	t
Electricity	480	kWh
Steam	3.80	t
Fuel (Natural gas)	12.0	Nm^3
Export:		
By-product AN (34.5%N)	3.4	t

Appendix 3

Consumption Figures for the Sulphur-Based Production

The data refers to a production of 2120 t/d complex fertilizer of 1-1-1 grade plus production of 1190 t/d of ammonium nitrate (34.5%) fertilizer.

The production scheme consists of several units with the following raw-materials and utility consumptions.

Sulphuric Acid Plant

Figures per 1 t/100% H_2SO_4

Sulphur	0.334 t
Electricity	56.00 kW
Steam credit (46 bar)	1.06 t

Phosphoric Acid Plant

Figures per 1 t P_2O_5 in phosphoric acid

Phosphate rock (30.4% P_2O_5)	3.41 t
Sulphuric acid	2.82 t
Electricity	160.00 kWh
Steam (2 bar)	2.40 t

NPK Granulation Plant

Figures refer to 1 t P_2O_5 in the product.

Phosphoric acid (as P_2O_5)	1.02	t
Nitric acid	1.78	t
Ammonia	0.75	t
Potash	1.68	t
Steam (2 bar)	0.10	t
Steam (15 bar)	0.45	t
Fuel (natural gas)	24	$N\ m^3$
Electricity	240	kWh

In addition to the complex fertilizer, a production of solid ammonium nitrate must be defined within the battery limit in order to balance the production.

For this section we have the following consumption figures:

Ammonium nitrate plant

Figures per 1 t solid ammonium nitrate fertilizer.

Nitric acid	0.787	t
Ammonia	0.211	t
Electricity	41.0	kWh
Steam (15 bar)	0.11	t
Steam credit (5 bar)	0.18	t

Appendix 4

Consumption Figures for Ammonia and Nitric Acid Plant

We have used a high efficiency natural gas based unit with the following consumption figures.

Figures are per 1 t NH_3

Natural gas feedstock	22.521 GJ	(616 Nm^3)
Natural gas fuel	6.288 GJ	(172 Nm^3)
Total natural gas	28.809 GJ	(788 Nm^3)

After meeting all the internal steam demands a total amount of 688 kg/t NH_3 at 46 bar and 389°C will be available. This steam can be passed through a condensing turbine or exported.

If the steam is passed through the condensing turbine with a steam/power ratio equal to 4.78 kg steam/kWh we achieve a total electrical output equal to 143.9 kWh/t NH_3.

After meeting the internal electricity demand of 100.8 kWh/t NH_3, the export could be 43.1 kWh/t NH_3.

Nitric acid plant

Figures per 1 t 100% HNO_3

Ammonia	0.29 t
Electricity	10.0 kWh
Steam, credit (46 bar)	0.31 t

Appendix 5

Typical Consumption Figures for Urea Ammonium Phosphate Production

The data should be considered as general:

Urea

Figures are given per 1 t product.

Ammonia	0.58 t
Steam (approx. 20 bar)	0.65 t
Steam (approx. 12 bar)	0.25 t
Electricity	21 kWh

NPK Complex Fertilizer

Figures are given per 1 t P_2O_5 in the product.

Steam (5 bar)	0.12 t
Electricity	177 kWh
Fuel(natural gas)	0.06 t

The data are taken from (7).

Appendix 6

Gross Energy Consumption of the Complexes

Summary

1. Norsk Hydro Nitrophosphate Complex:

1.1 Scheme A

		GJ/t P_2O_5
Phosphate rock	3.32 x 5	= 16.6
Potasium chloride	1.68 x 5,6	= 9.4
Natural gas to ammonia plant	788x 2.71 x 36.56/1000	= 78.1
Natural gas to NPK plant	12 x 36.56/1000	= 0.4
Gas to combustion turbine	168 x36.56/1000	= 6.1
Gross specific energy consumption		110.6

1.2 Scheme B

		GJ/t P_2O_5
Phosphate rock	3.32 x 5	= 16.6
Potasium chloride	1.68 x 5.6	= 9.4
Gas to ammonia plant	788x 2.71 36.56/1000	= 78.1
Natural gas to NPK plant	12 x 36.56/1000	= 0.4
Gas to gas boiler	59 x 36.56/1000	= 2.2
Electricity	0.575 x 10.8	= 6.2
Gross specific energy consumption		112.9

2. Sulphur Based Complex

		GJ/t P_2O_5
Phosphate rock	3.48 x 5	=17.4
Potasium chloride	1.68 x 5.6	= 9.4
Natural gas to ammonia plant	788 x 2.71 36.56/1000	=78.1
Sulphur	0.96 x 16.50	=15.8
Natural gas to NPK plant	24 x 36.56/1000	= 0.9
Gross specific energy consumption		121.6

3. Sulphur based NPK Complex with Urea-Ammonium Phosphate

		GJ/t P_2O_5
Phosphate rock	3.48 x 5	= 17.4
Potassium chloride	1.68 x 5.6	= 9.4
Gas to ammonia plant	788 x 2.71 36.56/1000	= 78.1
Sulphur	0.96 x 16.50	= 15.8
Gas to gas boiler	98 x 36.56/1000	= 3.6
Gas to UAPK granul.	69 x 36.56/1000	= 2.5
Electricity	0.339 x 10.8	= 3.7
Gross specific energy consumption		130.5

Appendix 7

Electric Power Consumption in the Nitrophosphate Process

Relative figures

NPK Wet Section		Approx. 66%
Agitators/pumps, etc.	Approx. 29%	
Cooling unit	" 23%	
Fans/blowers, etc.	14%	
NPK Dry Section		Approx. 22%
Ammonium Nitrate Section: Final Evaporation and Pan Granulation		Approx. 12%

Appendix 8

Steam Consumption in the Nitrophosphate Process

Relative figures

Evaporation of NP liquid (20 bar)	Approx.	21 %
Evaporation of AN solution (15 bar)		57 %
Miscellaneous 15 bar (ejectors, etc.)		3 %
Miscellaneous 5 bar		19 %

TA/82/20 Evaluation of complex fertilizer manufacture based on systematic energy accounting, by E. AASUM, S. FLATEBOE & R. GRONNERUD Norsk Hydro a.s., Norway

DISCUSSION : (Rapporteur : Mr. N. SIMOGLOU, PFI, Greece)

Q - Mr. K.C. KNUDSEN, Superfos, Denmark

Why did you choose for comparison (ref. page 20-3) a standard dihydrate phosacid process and not your own energy saving Fisons hemihydrate process presented in paper 17?

The sulphur-based process is characterized by a considerable surplus of low pressure steam. Let us assume that the data from paper 17 are used - and let us assume that the 2 bar steam and hot water from the sulphuric acid plant can be exported from the NPK complex and made useful in other parts of the factory or for town district heating. In that case we calculate less total energy consumption in the sulphur-based than in the nitrophosphate NPK-complex.

The decisive factors in the present evaluation seem to be firstly whether you can make use of all your low temperature calories, and secondly what price you have to pay per unit of energy in sulphur compared to gas or oil - provided that you put the value of sulphur as a raw material at zero.

A - The standard dihydrate phosacid process was chosen for the comparison because it is generally well accepted and has a high possibility in handling the wide variety of available commercial rocks. Moreover, the results of paper 17 was not known in detail when our paper was prepared.

After paper 17 was published we have, however, made the necessary comparisons and utilized specifically the energy information in that paper. Based on a gross specific energy consumption for the dihydrate process of 121.6 GJ/t P_2O_5 we see the following improvements for this hemihydrate version:

Increased phos. rock consumption	+ 0.1 GJ/t P_2O_5
Reduced sulphur consumption	- 0.6 " " " "
Gross spec. energy consumption with hemihydrate process	121.1 " " " "
Credit for electr. power export	2.9 " " " "
Net spec. energy consumption for hemihydrate process	118.2 " " " "

We agree with Mr. Knudsen on the importance of utilising the low grade heat. Town heating is interesting, but the possibilities seem limited to areas which already have an established system like in Sweden, Finland and Denmark.

For the sake of theoretical calculation, if one could economically fully utilize all the low grade heat, this would make another credit of maximum 6.4 GJ/t P_2O_5 for the sulphur-based process.

Thus the sulphur based case - with hemihydrate and maximum theoretical low-grade heat credit - would still come out with a slight disadvantage compared to the nitrophos-based route (111.8 GJ/t P_2O_5 vs 110.6 GJ/t P_2O_5).

Finally it is interesting to notice that sulphur at 140 $/t means an energy price of 8.5 $ /GJ using the combustion energy of 16.5 GJ/t sulphur as in the paper.

This means for example that the difference in GJ between the nitrophosphate alternative and the sulphur-based alternative in appendix 6 of the paper amounts to about 110 $/t P_2O_5 - still with sulphur as raw material at zero value.

Q - Mr. N. NICOTRA, ANIC SpA, Italy

In the paper, you present your process as energetically convenient in comparison with a sulphur-based NPK complex,... ... also if this last one is "constructed" to produce a nearly 1:1:1 NPK and AN.

We could agree with your calculation in the case of a traditional factory, but with the existing energy recovery improvements in sulphuric and phosphoric acid plants and NPK granulations, we think that the situation will be balanced and the interest in your process consists in the difference of raw materials and their costs:

- For example: following your Energy Accounting method, what would be the new situation for a sulphur based and a nitrophosphate factory with the following considerations:
- Sulphuric acid, phosphoric acid and NPK granulation plants consume half of the indicated consumption of Kwh and fuel gas,
- Phosphoric acid and NPK granulation don't need steam because phosphoric acid is consumed at 42% concentration, utilizing, in the dihydrate process, heat recovered from sulphuric acid coolers
- The recovered energy in the sulphur based plants produces electrical power benefits that must be produced in the nitrophosphate process from natural gas in a bigger cogeneration unit.

A - With regard to the utility consumptions we have the following comments:

- In the sulphuric acid plant the electricity consumption is directly linked with the surplus steam. It would seem difficult to reduce the quoted electricity demand without also reducing the steam credit.
- The electricity consumption for a dihydrate process seems to be in good agreement with information for other processes (see paper 17).
- We selected an NPK granulation process with a recycle ratio of 3:1. A lower ratio can be used and accordingly a lower electricity consumption can be obtained, but this would require higher steam consumption. The granulation route we chose had the highest consumption in L.P. steam. This is essential for a good overall energy result in the sulphur-based complex.
- The two last questions deal with the utilization of low and high grade heat from the sulphuric acid plant. Through our calculation on the hemihydrate process (where the acid concentration ex filter is 42%), we feel we have outlined the situation. The nitrophosphate process ends up with a lower net specific energy requirement even if both electricity production and low grade heat utilisation is taken into account for the sulphur-based version.