International Fertilizer Industry Association

# ISMA* Technical Conference

## The Hague, The Netherlands
## 13-16 September 1976

**In 1982, the name of the International Superphosphate Manufacturers' Associations (ISMA) was changed to International Fertilizer Industry Association (IFA).*

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TA/76/15

# LOW INVESTMENT AND OPTIMIZATION IN THE PRODUCTION COSTS OF AN UREA-MAP-NPK FERTILIZER COMPLEX.

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## SUMMARY

A fertilizer complex, owned by S.A. CROS in the South East of Spain, is described here. This complex was the result of a decision taken to enlarge a previous smaller fertilizer plant.

We shall demonstrate that the fact of developing it our way, by constructing Urea, MAP and NPK units, has had de consequence of having available a number of units at a low investment cost, and also, the possibility of producing a wide range of nitrogen, binary and ternary fertilizers with an appreciable reduction in the production cost.

A comparison in the production of DAP between a conventional process and the NPK CROS process, gives a clear idea of some advantages of the complex, and also the advantages of the CROS process.

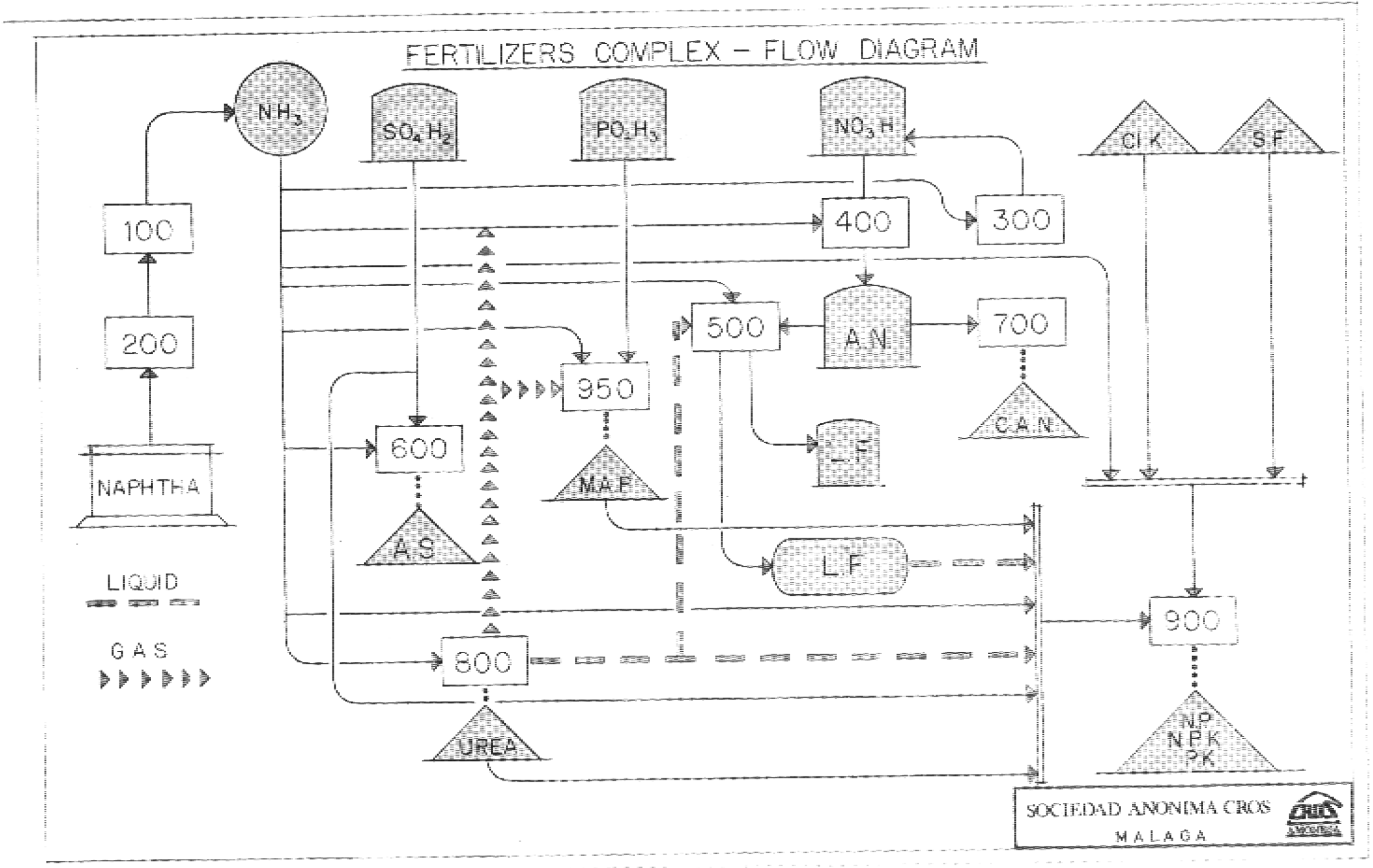
## SITUATION AND DESCRIPTION OF THE COMPLEX

In the outskirts of Málaga (Spain), S.A. CROS has a complex for the production and distribution of nitrogen and NPK fertilizers.

Originally, the plant had a basic structure in order to produce a wide range of nitrogen fertilizers, that nowadays includes others such as urea, and also binaries and ternaries such as MAP, DAP and NPK in general.

Basically, and referring to process units, the plant is composed of an ammonia unit, Kellogg license, with a capacity of 109.000 Tn/yr., and a naphtha desulphuration unit to treat about 60.000 Tn/yr., also Kellogg license.

This ammonia obtained is the raw material for different fertilizers and we have four possibilities to use it:


FERTILIZERS COMPLEX - FLOW DIAGRAM
NH3
SO4H2
PO4H3
NO3H
Cl K
S.F
100
200
NAPHTHA
400
300
500
A.N.
700
950
600
C.A.N.
L.F
M.A.P.
A.S
L.F
LIQUID
GAS
900
800
UREA
N.P
N.P.K
P.K
SOCIEDAD ANONIMA CROS
MALAGA

- Nitric acid - Ammonium Nitrate, Kellogg license, to produce Calcium Ammonium Nitrate (CAN) of three different compositions: 20,5% $N_2$, 26% $N_2$ and 30% $N_2$ in a granulation plant, to consume 100.000 Tn/yr. of nitric acid.
- Ammonium Sulphate unit, Swenson license, with 98% sulphuric acid with a capacity of 110.000 Tn/yr.
- Urea unit, a once-through stripping process, Stamicarbon license, with a total capacity of 100.000 Tn/yr.
- MAP unit, Fisons license, with a production of 105.000 Tn/yr.

The products of these units can be sent to storage or can be used as the raw materials, in the intermediates or final stages, to produce others, such as Ammonium Sulphate Nitrate 26% $N_2$, liquid fertilizers with or without pressure and all the different types of NPK fertilizers. This NPK unit, CROS license, has a production capacity of 120.000 Tn/yr.

Originally the complex was designed to produce ammonia, nitric acid, ammonium nitrate, ammonium sulphate, and liquid fertilizers. The main idea was to obtain the best heat balance in order to use the disposable steam from ammonia and nitric acid plants.

The development of the complex, with the installation of Urea, MAP and NPK has been able to use the advantages from the first installations and carry out this new investment in order to obtain these three objectives.

- Minimum investment.
- Lower production costs.
- High quality products.

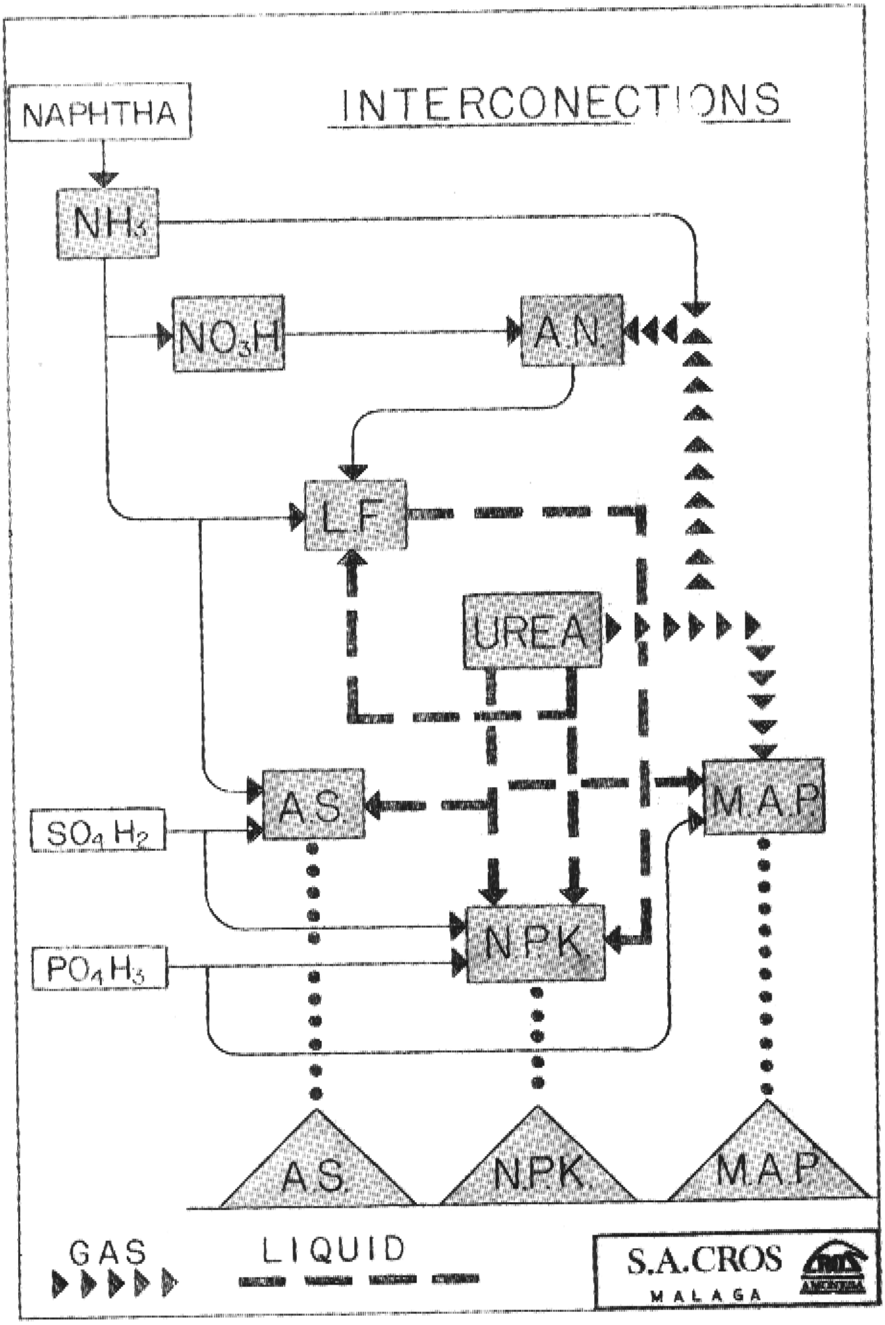
Moreover, we have been very careful to get a high factor service for for the gases or liquids from some plants to the others, giving different possibilities in the use of these gases and/or liquids.

The service factor in most of the cases is over 99%.

The complex produces 600.000 Tn/yr. approximately and receives 400,000 Tn/yr as raw materials, so it represents a movement of about 1,000,000 Tn/yr.

As a matter of fact, the actual tendency is to use the raw materials in the lowest level of energy in order to:

15 - 4


INTERCONECTIONS
NAPHTHA
$NH_3$
$NO_3H$
A.N.
L.F.
UREA
A.S.
$SO_4H_2$
M.A.P.
N.P.K.
$PO_4H_3$
A.S.
N.P.K.
M.A.P.
GAS
LIQUID
S.A.CROS
MALAGA

- Avoid extra operation costs.
- Make the most of the energy content in the raw materials themselves.

We can show many cases of optimum utilization of raw materials such as:

- Urea solution in NPK.
- Phosphoric acid in NPK.
- Off-gases from urea unit in MAP and/or A. N.
- Ammonia gas from the synthesis refrigeration in ammonia unit as raw material in Ammonium Nitrate, Ammonium Sulphate and MAP.

Later on we will evaluate the production costs of some intermediate products and some steps in the production and we will see what the economical influence is.

To sum up, in the complex we produce: Ammonia, Nitric Acid, Ammonium Nitrate, Calcium Ammonium Nitrate, Nitrosulphate, Liquid Fertilizers, Ammonium Sulphate, Urea, Mono-ammonium Phosphate and a wide range of binaries and ternaries in the NPK unit. For these we are using as raw materials: Naphtha, Air, Sulphuric Acid, Phosphoric Acid, Limestone, Potash and Superphosphate.

## INVESTMENT

At the moment we are going to select a process to build a urea unit, it is possible to choose between two different alternatives:

- Total or partial recycle plant.
- Once-through plant.

In practice, the investment in a urea plant is proportional to the size and the type of the plant and changes approximately according to the following Table I.

It is useful, in a complex where it is possible to consume or to export MAP, to install a MINIFOS unit to produce MAP. The capacity of the MAP plant is, depending on the off-gas disposable in the ammonia concentration in it, of about 1 Tn of urea/1 Tn of MAP on dry basis. Also you can increase this ratio to 1, 25.

CROS has made experiments and has developed the technology to use the off-gas as an alternative in an Ammonium Nitrate unit with good performance and high yelds in the neutralization. (See Table II).

TABLE I

| Tn/yr. | Total recycle | | Once-through | |
|---|---|---|---|---|
| | Conventional | Stripping | Conventional | Stripping |
| 50.000 | 1,27 | 1,34 | 0,80 | 0,84 |
| 100.000 | 1,52 | 1,60 | 0,95 | 1,00 |
| 200.000 | 2,55 | 2,70 | 1,67 | 1,75 |
| 300.000 | 3,30 | 3,55 | 2,10 | 2,22 |

The MAP unit with the necessary phosphoric acid storage, gives the opportunity to the NPK unit to receive another liquid raw material, phosphoric acid 52% $P_2O_5$.

The possibility of using this raw material decreases the production costs of the high NPK fertilizers such as 15-15-15, 17-17-17 or 19-19-19 where we also employ concentrated urea solution and therefore have the possibility of making MAP and DAP at lower costs than the typical processes.

The use of urea solution also saves energy in concentration, prilling and transportation, as we will see later on.

The total investment for the complex UREA-MAP-NPK is about 16 MM \$ (1974) to produce 100,000 Tn/yr., 105,000 Tn/yr., and 120,000 Tn/yr. respectively.

Showing as a proportion the investment of the three units, the percentages for each one are the following:

| UREA | MAP | NPK |
|---|---|---|
| 64,83 % | 8,87 % | 26,30 % |

Taking into account the off-sites, warehouses, stores and other buildings, the distribution remain as follows:

| UREA | MAP | NPK |
|---|---|---|
| 61,40 % | 14,20 % | 24,40 % |

We have included in this percentage for the MAP the phosphoric acid storage tank.

As can be seen in Table I, the investment for a total recycle urea unit of the same capacity, is similar to that necessary to build an equivalent complex.

Later on, we will study the production costs of different products and we will be able to compare both solutions and get to know which are the most important advantages of our solutions.

The disposal of urea (prill or solution), phosphoric acid and ammonia provides the CROS process with special advantages for the NPK production, because the production costs are reduced due to the savings in the production of intermediate products.

TABLE II

| LOSSES | $NH_3$ gr/l | A. N. gr/l |
|---|---|---|
| With off-gas * | 8. 2 | 9. 2 |
| Without off-gas | 4. 4 | 2. 6 |
| Yield $N_2$ % | 99. 7 | 99. 1 |

We can sum up the main investment differences between a total recycle urea unit and a once-through urea unit as follows:

1. - Smaller size of the synthesis equipment (about 10% less) due to a lower $H_2O$/Ur ratio.
2. - The decomposition equipment must be smaller, because it receives less liquid and gas (about 12% less).
3. - The installation of a rectifying column is not necessary.
4. - The low pressure condensation stage is not installed in the once-through unit. This stage is composed of:
   - 4. 1. - Low pressure condenser.
   - 4. 2. - Scrubber.
   - 4. 3. - Refrigeration system.

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* These are the average results over four months working under these conditions.

A. N. unit at 130% load.

4.4. - Carbamate pump.

4.5. - Instrumentation.

4.6. - Accesories.

5. - The concentration equipment is in once-through unit smaller in size because the urea solution obtained at the outlet of decomposition is higher in once-through units than in total recycle units. In that case the difference in size can be 25-30.%.

## REDUCTION IN THE PRODUCTION COSTS

Afterwards we will analyze separately the advantages that each one of the units by themselves offer, and the advantages resulting from their joint utilization.

Urea Unit

- The 25 ata steam consumption is about 10 % lower than in the total recycle urea units.
- The advantage of working with a very low $H_2O$/Ur ratio of 1.0, in the outlet of the stripper and 1.2 in the liquid outlet of the reactor, offers the possibility of sending out about 15 % more low pressure steam than in total recycle urea units, steam that it is possible to use to move turbines, etc., saving energy. This saving represents 0.110 Tn. low pressure steam per Tn. of urea more in the once-through process.
- Due to the minimum water presence in the reactor, the ammonia and carbon dioxide conversion efficiencies must be optimum at relatively low pressure.
- The normalization of the process conditions, and the operation of the plant is easier and it supposes higher production and a consumption index nearer the ideal figures.

The differences between the two components can be corrected in an easier way because it is possible to purge the excess of the uncorrected reactant. This point is always important but mainly in the start-up.

From our experience we can say that the necessary time to be purging and excess of gas during a start-up, from the moment we begin to feed ammonia till we produce urea solution is only 1 - $1^1/_2$ hours of that time must the gas be purged to the atmosphere.

So the pollution problem has a minimum importance.

- The ammonia performance, the expensive raw material, is higher than in a total recycle process, because the ammonia off-gas is used to neutralize and acid, phosphoric or nitric acid.

- As the urea unit is less complicated, the service factor is higher and the maintenance costs much lower.

- As our urea unit was designed as a stripping process instead of a conventional one, the ratio ammonia fed/urea produced is lower, 0.71 design, but in practice it is 0.67 against values as high as 1.23 for conventional process. The reduction of ammonia fed is 85%; therefore the relationship with the neutralization units is smaller.

- The unit has a high elasticity providing an ammonia export from 20% over design to 25% below design. This is important because it allows us to work with the unit in different moments with different capacities according to the market requirements.

An estimation of the operation costs of a total recycle urea unit versus a once-through urea unit gives the following results:

| | | |
|---|---|---|
| Ammonia | : | 1 - 2 % |
| Carbon dioxide | : | Negligible |
| Steam | : | 10 % |
| Electricity | : | ( 3 % ) |
| Cooling water | : | 25 % |
| Maintenance | : | 60 % |
| Production labor | : | - |
| Depreciation | : | 60 % |
| Taxes and Insurance | : | 50 % |

All these items give a difference in the production cost of about 15 % more in a total recycle plant.

MAP Unit

- The ammonia used as raw material is supplied, vaporized and hot from the urea unit, therefore it is not necessary to install a vaporizer or to consume steam.

- The MAP unit, according to the desired production can be made in one or two neutralization stages. In the latter case it will be necessary to feed some ammonia gas to the second reactor. In this case the unit is more complicated but the nitrogen performance is a little higher.

NPK Unit

- The versatility and high performance in the fixation of the ammonia are the most important characteristics of this unit.
- With the possibility of using the "T" reactor and the ammonization system, it is possible to fix over 200 Kgs. ammonia per Tn. of finished product.
- The possibility of using raw materials such as phosphoric acid and urea solutions at different concentrations, assumes important savings in energy for some formulations as we will se later on.
- The use of phosphoric acid saves the production costs of MAP and moreover fuel-oil for the drying of the granules. Also the granulation performance is better than with solid MAP.

Joint Utilization

The possibility of having the three units beside one another provided us with extra profits from the energy point of view.

We shall now see and try to evaluate the most important savings:

Use of urea solution in NPK

The cost reduction for the different items is:

| | | | |
|---|---|---|---|
| - Prill | : | 0.20 $/Tn. | (1975) |
| - Transport | : | 0.15 $/Tn. | (1975) |
| - Storage | : | 0.60 $/Tn. | (1975) |
| - Handling | : | 0.15 $/Tn. | (1975) |
| Total ....... | | 1.10 $/Tn. | (1975) |

We have not taken into account the losses you necessarily incur in the handling of any product.

Also another advantage is the measurement of a liquid versus the measurement of a solid. This system has more accuracy and is cheaper to maintain and to install.

Use of ammonia water in NPK and/or MAP

The disposal of about 3.5 m3/hr. of 2.5% ammonia water solution and traces of urea, allows the recovery of the ammonia by stripping or using the solution directly in the NPK unit to granulate, or in the MAP unit to control the reaction temperature, if we use the ammonia water solution in these units we save:

1. - Steam to make the stripping: 180 Kgs/m3 treated solution.
2. - Residual urea, passing it to NPK or MAP products: 7 Kgs/m3 treated solution. (This represents about 0.2 % of the urea production).

These two items represent a saving per year of:

5,000 Tn. low pressure steam.

200 Tn. urea.

The use of off-gas from urea unit in MAP unit

The use of these gases at 130ºC saves an important amount of energy, equivalent to the heating, evaporation and overheating of the necessary ammonia to produce the MAP. An evaluation indicates about 4,700 MM Kcal/yr.; that represents between 8,500 - 9,000 Tn/yr. low pressure steam.

The use of phosphoric acid in NPK

The use of phosphoric acid in NPK has certain advantages, among them we can show the following:

- Making the most of the reaction heat to dry the product with the saving in fuel-oil.

In formulas such as 16-48-0 or 15-15-15 the consumption is reduced to such low level as 3-4 Kgs/Tn. finished product, and in the 16-48-0, we maintain the burner alight for safety reasons rather than for necessity.

- The granulation is easier due to the temperature increase in the granulator.

- It is possible to use phosphoric acid of a lower concentration than the one employed in the MAP unit. The lowest concentration in the "T" reactor is 40-42 % $P_2O_5$

- The saving of the production cost of MAP is:

| | | | | |
|---|---|---|---|---|
| - Salaries | : | 1, 10 | $/Tn. | (1975) |
| - Energies | : | 0, 53 | $/Tn. | (1975) |
| - Maintenance | : | 0, 30 | $/Tn. | (1975) |
| - Administration | : | 0. 42 | $/Tn. | (1975) |
| - General | : | 0. 04 | $/Tn. | (1975) |
| - Depreciation | : | 1, 56 | $/Tn. | (1975) |
| Total ........... | | 3, 95 | $/Tn. | (1975) |

We have not taken into account the raw materials because the performances are similar or even more favorable to the NPK unit.

The production cost in the NPK unit, is only the cost of pumping the acid if the MAP unit did not exist, it would only be the installation cost of the phosphoric acid tank, which represents, over the total MAP investment, a 20 %. So we can assume the MAP production cost in the NPK unit is 0, 6 - 0. 7 $/Tn. (1975).

## SUMMARY

### REDUCTION IN THE EVALUABLE PRODUCTION COSTS

| | | | Thousands $ (1975) |
|---|---|---|---|
| **From Urea** | | | |
| 1.- Reduction 25 ata. steam | : | 13,500 Tn/yr. : | 117 |
| 2.- Higher 4.5 ata. steam export | : | 11,000 Tn/yr. : | 80 |
| 3.- Lower maintenance costs | : | 6 % of the investment : | 230 |
| 4.- Lower cooling water costs | : | 2,376,000 m3/yr. : | 45 |
| **From MAP** | | | |
| 1.- Using ammonia water solution | : | | |
| . Saving 4.5 ata. steam | : | 1,700 Tn/yr. : | 12 |
| . Recovery of urea | : | 70 Tn/yr. : | 6 |
| 2.- Using ammonia vaporized | : | | |
| . Saving 4.5 ata. steam | : | 8,500 Tn/yr. : | 61 |
| **From NPK** | | | |
| 1.- Using ammonia water solution | : | | |
| . Saving 4.5 ata. steam | : | 3,300 Tn/yr. : | 24 |
| . Recovery of urea | : | 130 Tn/yr. : | 12 |

2.- Using phosphoric acid

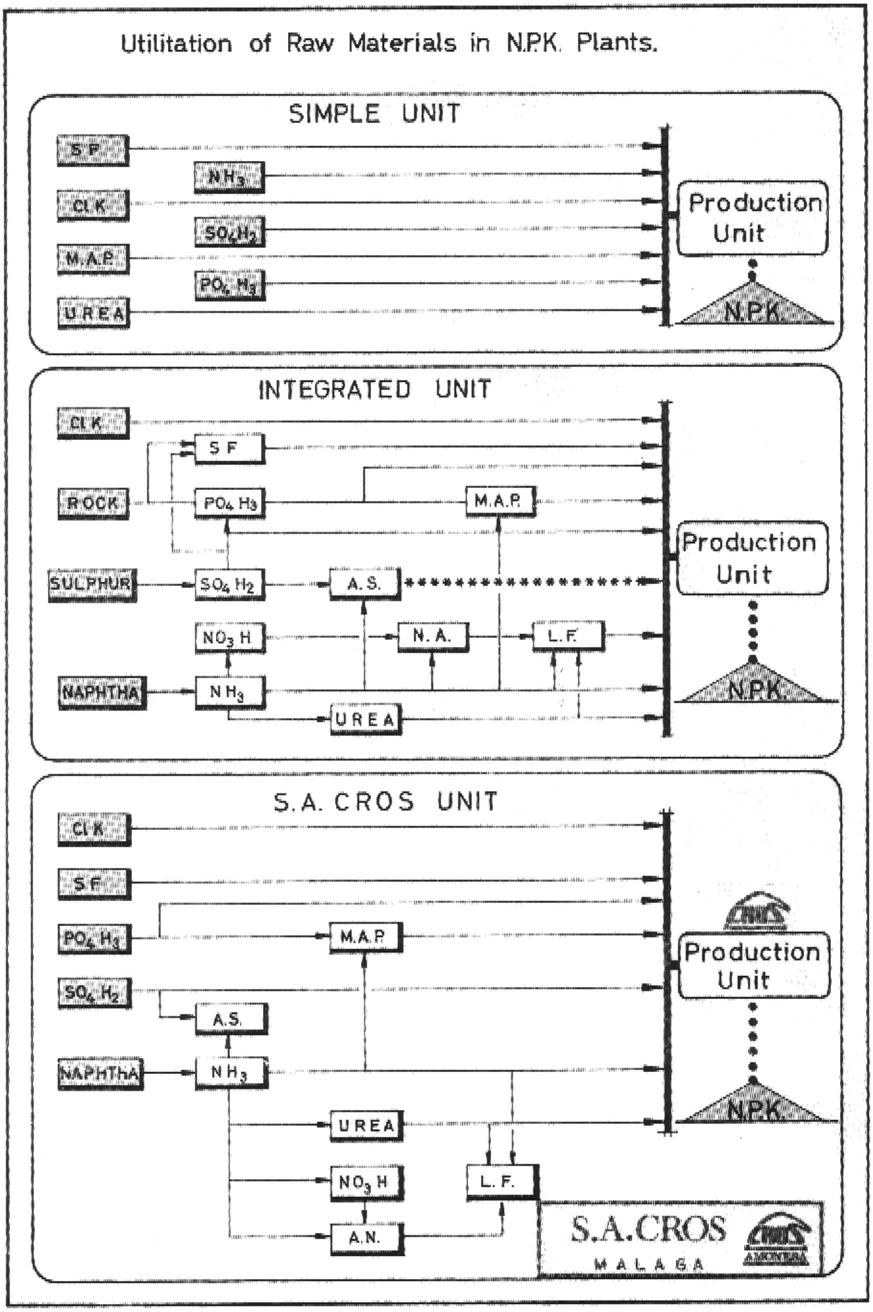
. Reduction of MAP production cost : : 3.25 $/Tn. MAP made in NPK unit.

. Reduction in fuel-oil consumption : 14 Kgs/Tn NPK : 1.26 $/Tn. NPK type 15-15-15; 17-17-17.

3.- Using urea solution : : 1.10 $/Tn. of urea consumed in NPK unit.

Basis :

| | | | |
|---|---|---|---|
| Price fuel-oil Bunker C | : | 90 $/Tn. | (1975) |
| " urea | : | 90 $/Tn. | (1975) |
| " 25 ata. steam | : | 8.5 $/Tn. | (1975) |
| " 12 ata. steam | : | 7.5 $/Tn. | (1975) |
| " 4.5 ata. steam | : | 7.0 $/Tn. | (1975) |
| " 100 m3 C.W. | : | 1.8 $ | (1975) |


Utilitation of Raw Materials in N.P.K. Plants.
SIMPLE UNIT
S F
N H3
Cl K
SO4 H2
M.A.P.
PO4 H3
U R E A
Production Unit
N.P.K.
INTEGRATED UNIT
Cl K
S F
ROCK
PO4 H3
M.A.P.
SULPHUR
SO4 H2
A. S.
NO3 H
N. A.
L. F.
NAPHTHA
N H3
U R E A
Production Unit
N.P.K.
S.A. CROS UNIT
Cl K
S F
PO4 H3
M.A.P.
SO4 H2
A.S.
NAPHTHA
N H3
U R E A
NO3 H
L. F.
A.N.
Production Unit
N.P.K.
S.A.CROS
M A L A G A

# ADVANTAGES OF THE CROS PROCESS FOR THE PRODUCTION OF DAP

The NPK unit, that S. A. CROS licenses, is able to process a wide range of different raw materials, but the main interest is the possibility of avoiding the intermediate product using raw materials such as phosphoric acid, urea, ammonia and sulphuric acid when this later is necessary.

This unit that S. A. CROS has in the Málaga complex is a semi-integrated unit, very suitable for producing high NPK fertilizers such as 15-15-15, 17-17-17, 19-19-19, 16-48-0, etc., owing to the possibility it has of using the most favorable raw materials in the best form.

As an example, we are going to compare the process and operation costs between the DAP made by the CROS process and a conventional one.

The figures written here refer to two existing units in Spain, one to produce DAP only and the other, the S. A. CROS NPK unit in Málaga.

## Investment

The estimated investment for the installation of a conventional unit is 75-80 % over and above the CROS unit.

Also it is important to take into account that we are comparing a unit to produce DAP with another versatil unit, the CROS one, to produce NPK and also MAP and DAP.

## Operability

We assume the description of the conventional process is well known and it can be found in the technical literature.

The advantages from the production point of view the CROS process represents are summed up in the following items:

- The size of the "T" reactor is very small and the cost compared to a normal reactor 317-L and a volumen of about 60 m3 is easy to understand there is a big difference.
- There is not pump equipment. It is necessary only to pump the phosphoric acid from the storage tank to the "T" reactor and granulator.
- Substitution of the scrubber at the gas outlet of the reactor, which is big and of 317-L material, for an empty polipropylene conventional one, reinforced with glass fiber.

- Utilization of liquid ammonia instead of ammonia gas with the corresponding saving in equipment and energy to vaporize it.

- Possibility of feeding phosphoric acid to the granulator using the reaction heat.

- Lower fuel-oil consumption. It is 8 Kgs/Tn finished DAP in the CROS process against 70-80 Kgs/Tn finished DAP in a conventional one.

- Possibility of using phosphoric acid with a $P_2O_5$ content of about 40-42%.

- The recycle in the unit is decreased to 2-3, against about 6 in the conventional process.

- The granulation performance is very good and the humidity in the outlet of the granulator is between 1.0 and 1.7%.

- The dryer is smaller and the necessary burner too. Generally speaking the size of the equipment is smaller in the CROS unit than in the conventional one.

Reduction in the Production Costs

From the point of view of cost we will try to show below the most important facts and also evaluate them.

Use of liquid ammonia

Saving in 4.5 ata. steam: 0.120 Tn/Tn of DAP.

Lower fuel-oil consumption

Saving: 60-65 Kgs/Tn of DAP.

Lower maintenance costs

Saving: 50% approx.

Lower depreciation

Saving: 40% approx.

In Table III we have collected and evaluated these items.

Operating Conditions

The operating conditions in the DAP unit, CROS process, are the following:

Phosphoric Conc. to the "T" Reactor : 40 - 42 % $P_2O_5$

Pressure in the "T" Reactor : 3.5 - 4.0 Kgs/cm2.

| | | |
|---|---|---|
| Ammonia | : | Liquid; 0ºC. |
| Temperature of the "T" Reactor | : | 120 - 125 ºC |
| Ratio N/P | : | 1,3 - 1.35 |
| Phosphoric conc. to the Granulator | : | 42 - 50 % $P_2O_5$ |
| Granulator temperature | : | 80 ºC |
| Recycle | : | 1 : 2 - 1 : 4 |
| $N_2$ yield | : | 98 % |
| Fuel-oil consumption | : | From 0 to 8 Kgs/Tn. |

It is possible to work with the burner switched off, but for safety reasons, to avoid troubles at any one moment with the granulation, it is recommended to use the burner switched on at the minimum.

TABLE III

| ITEM | CROS PROCESS | CONVENTIONAL PROCESS | DIFFERENCE $/Tn. (1975) |
|---|---|---|---|
| 4,5 ata. steam | - | 120 Kgs/Tn. | 0.96 |
| Fuel-oil | 8 Kgs/Tn. | 70-80 Kgs/Tn. | 6.20 |
| Maintenance | 1.4 $/Tn. | 2.4 $/Tn. | 1.00 |
| Depreciation | 2.3 $/Tn. | 4.0 $/Tn. | 1.70 |
| Electricity | - | - | - |
| Total ........................................ | | | 9.86 |

Production of other binaries

In a similar way as we have just explained, it is also possible to produce granulated MAP in the NPK unit with the following advantages:

- Granulated product. Better properties for storage purposes and possibility of using it as a direct fertilizer.
- Lower humidity content, 1-2 % only, with improvement in caking properties and saving in transport.
- Possibility of using phosphoric acid of a $P_2O_5$ concentration of 40-45 %.

- Use of liquid ammonia directly in the neutralization of the phosphoric acid with the corresponding saving in equipment and energy.