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

International Fertilizer Industry Association - Secretariat: 28 rue Marbeuf - 75008 Paris - France
Tel. +33 1 53 93 05 00 - Fax +33 1 53 93 05 45/47 - ifa@fertilizer.org - www.fertilizer.org

LIQUID FERTILIZER PRODUCTION
STRUCTURE OF A DISTRIBUTION NETWORK

By F. FRAITEUR - Sté de Prayon (Belgique)

INTRODUCTION

The rapid development of agriculture both in the farm size and agricultural aspects as well as the means needed to implement them led Société de Prayon, nearly seven years ago, to undertake investigating the potential possible use of liquid fertilizers. This investigation, in harmony with the programme of production diversification of the Company, which for many years has contributed in the development of phosphoric acid manufacturing techniques, finally resulted in 1970 in the establishment of an integrated system including production, marketing and distribution of straight, NP and NPK liquid fertilizers.

Because of their nature and application technique, liquid fertilizers satisfactorily fulfil the wishes of a modern and progressive farmer :

- substantial saving of labour, which is in short supply
- rapid and accurate application
- possible combined fertilizer - pesticide treatments
- possibility of preparing a true "tailor made" formulation.

Briefly, they undoubtedly offer to the farmer a number of substantial economic and agricultural advantages.

For the producer, in an integrated NPK liquid fertilizer system such as the one just mentioned, the P nutrient, e.g. phosphorus pentoxide, obvious plays a predominant role which puts the producer of phosphoric acid in a privileged position.

Indeed in liquid fertilizers P_2O_5 must be completely soluble, highly concentrated, non corrosive and finally in such a form that it gives the resulting fertilizers satisfactory physical and chemical properties (no solid, salting out point as low as possible, good storage properties).

For that reason, the producer of complex liquid fertilizers must above all have a basic high quality P solution.

The ammonium polyphosphate solution fulfils that need, provided its polymerized P_2O_5 content is sufficient and, in any case, higher than 50 % of the total P_2O_5 content.

It can be obtained by two different ways, namely :

- the direct way involving neutralization of 54 % phosphoric acid solution by ammonia using the heat of reaction as phosphoric acid polycondensation energy

- the superphosphoric acid route involving phosphoric acid polycondensation using an outside heat source and separate neutralization of the superphosphoric acid by ammonia.

Within these two procedures, a number of processes are presently available. The purpose is not to deal with them here but to describe, as comprehensively as possible, the production and distribution structure which Société de Prayon has been using.

The system finally adopted results from a thorough investigation carried out mainly with Belgian farmers. It has operated quite satisfactorily for nearly five years ; therefore, we felt it appropriate to discuss it, but the reader may compare it with others which have already proved effective in other countries,albeit in a different agricultural context.

Manufacture of liquid ammonium polyphosphates

If, at present, there are different processes to manufacture directly liquid ammonium polyphosphates, e.g. by reacting anhydrous ammonia with 54 % P_2O_5 phosphoric acid, when the choice was made, these processes, although known, did not offer sufficient guarantee both from the technology and the product quality aspects.

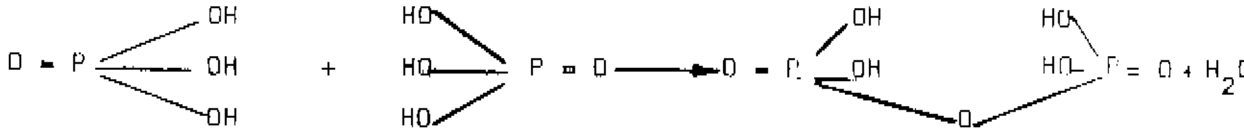
Under these conditions and since a quick decision was necessary, we chose the process which could be called "conventional", namely superphosphoric acid manufacture and neutralization of the acid by anhydrous ammonia. At the time the system had already been industrially proven and the main difficulty was in the selection of the superphosphoric acid process, namely the so-called submerged combustion or vacuum evaporation processes. After thorough analysis, the submerged combustion process was finally retained because it resulted in a polyphosphate solution with a high polymerization rate, which gave excellent chemical and physical qualities.

Amongst them, one could in particular mention the ability to sequester impurities brought about by wet process phosphoric acid which depends on the degree of polymerization or polycondensation.

Superphosphoric acid production

54 % P_2O_5 phosphoric acid is fed in the evaporator (1) via the gas outlet duct (4) so as to recover most of the energy from the gas and to cool them before introducing them into the scrubbing circuit and finally to discharge them through the stack.

In the evaporator, the phosphoric acid introduced is heated to a temperature near 300° C by means of a hot gas generator (2) including a natural gas burner fed with combustion air by means of a compressor (3). The combustion carried out under pressure, at a level lower than that of the liquid mass contained in the apparatus, results in a very vigorous mixing of phosphoric acid with combustion gases. This heat exchange achieved by direct contact between the two fluids results on the one hand in the supply to phosphoric acid of enough energy to vaporize its dilution water and on the other in the energy necessary for breaking the chemical bonds which promotes the poly-condensation process releasing molecular constituent water of phosphoric acid according to the reaction which, in a first step, could be written :



Thus pyrophosphoric acid $H_4P_2O_7$ is obtained which, in the polyphosphoric acid range has most interesting sequestering properties.

Then, by reacting pyrophosphoric acid with orthophosphoric acid according to the same process as above, tripolyphosphoric acid $H_5P_3O_{10}$ is obtained, and so forth.

Superphosphoric acid, a mixture of orthophosphoric acid and of the poly-phosphoric acids formed, is produced continuously in the evaporator and then to a cooler (8) which lowers the temperature to nearly 60° C mainly to reduce and even eliminate its corrosiveness before taking it to storage. In order to avoid reversion of polyphosphoric acid, superphosphoric acid must be stored in the absence of humid air ; in addition, to enable further handling of that acid, the storage temperature must be kept round 60° C.

The gases discharged from the evaporator are first filtered (4) and thoroughly scrubbed (5) in order to recover most of the P_2O_5, since the total P_2O_5 efficiency is around 99 %. Dilute phosphoric acid, recovered by scrubbing, accounts for 3-4 % of the amount of phosphoric acid fed to the evaporator, expressed as P_2O_5. The gases are then scrubbed with water (5) before being discharged to the atmosphere (7) resulting in a very low effluent content.

The quality of the superphosphoric acid produced, illustrated by the rate of conversion into polyphosphoric expressed by the polymerized / total P_2O_5 ratio in the acid concerned, usually exceeds 65 %.

The high conversion rate gives superphosphoric acid sequestering properties largely sufficient for the subsequent operations of ammonia neutralization and storage of the products obtained.

The industrial plant referred to has a capacity exceeding 100 t P_2O_5/24 h and the quality of the superphosphoric acid is such that it contains 65 % polymerized P_2O_5. The operational rate, taking account of weekly maintenace stops, is 88 %. This stop is necessary for cleaning the burner tube at the end of which metaphosphate and iron and aluminium insolubles, which inevitably form in this zone at very high temperatures, accumulates. The plant is controlled by one man per 8 hour shift.

Manufacture of liquid ammonium polyphosphate

Superphosphoric acid stored at 60-65° C is fed to a stainless steel pipe reactor by means of a volumetric pump together with anhydrous ammonia previously vaporized. A continuous addition of water, together with reagents, enables to control the temperature of the strongly exothermic reaction, as well as the volumetric mass of the polyphosphate solution obtained.

The reaction product obtained is then fed to the top of a packed cooling tower (2) where it falls countercurrent to a stream of air induced by 2 suction fans (4). The polyphosphate solution cooled down to 50° C is collected in a tank (3).

In the collecting tank N° 3, the final adjustment of the pH of the ammonium polyphosphate solution is achieved by a gaseous NH_3 injector. The solution is then sent to storage with a centrifugal pump (6) and partially recycled to the collecting tank to make the mass homogeneous.

pH and product density are continuously measured on the recycled fraction.

The reversion of polyphosphates into orthophosphates during the neutralization reaction of superphosphoric acid by ammonia is limited to a maximum of 5 % to obtain finally a NP solution with a maximum polyphosphate content of 60 %. The high polymerization rate gives such a quality to the product that it can be safely stored for a few months.

The ammonium polyphosphate solution contains, in terms of volume, 15 % N and 50 % P_2O_5 ; the pH is 6.4 and density 1.410 ; the salting out temperature is 20° C. The plant capacity exceeds 100 t/24 h P_2O_5 with a 97 % operational rate and it is controlled by one man per 8 hour shift.

Ammoniation of superphosphoric acid in a T reactor developed by Tennessee Valley Authority at Muscle Shoals (Alabama) is easily adaptable with a very limited investment to the process of manufacture of ammonium polyphosphate solutions just described.

It would still improve the quality of the finished product obtained, and it should substantially increase the production capacity of the existing plant.

Production of NPK liquid fertilizers

Because of the prospect of an integrated liquid fertilization in Belgium we became interested in the manufacture of liquid NPK fertilizers.

These fertilizers can be divided in two types :

- clear NPK liquid fertilizers where all three nutrients N, P and K are completely solubilized. These fertilizers are generally present as clear solutions.

- NPK liquid fertilizers in suspension where all three nutrients N, P and K or simply one of them are only partly solubilized, e.g. part of the amount added to the fertilizer as solid particles uniformly distributed and kept in the medium by means of a suspension agent (colloidal clay). These fertilizers are present as an opaque and partly consistent supersaturated solution.

It can easily be understood that suspension fertilizers have a substantially higher nutrient concentration than clear liquids which justifies the increasing interest they give rise to at present. Indeed, although the storage and handling techniques of these fertilizers are more complicated than those applying to clear fertilizers, however, they behave like liquids with all the advantages it implies.

The manufacture of these two types of fertilizers is done at Prayon in the same plant and according to the same principle, by successive batches of about 10 tons as follows :

- an inclined bottom tank (1), with agitation, put on a weight scale, is fed successively from a 3 compartment tank (2) with preset amounts, according to the anticipated ratio, of :

  - 39-0-0 urea nitrate solution with the nutrient N

  - NP 15-50-0 solution containing mainly the nutrient P

  - water necessary for adjusting the concentration of the fertilizer formulation to be produced, preheated to 60° C.

When dealing with suspensions, the suspension agent is added through the screw and gelification is achieved. As soon as a sufficient gelification is obtained, the necessary amount of potassium chloride or sulphate is introduced via the extractor (3) the bucket elevator (4) and the screen (5).

When the medium becomes uniform, the whole product is sent to storage tanks by the horizontal centrifugal pump (7).

The NPK liquid fertilizer plant has a capacity of 500 t/24 h whether of clear liquids or suspensions. Two men per 8 hours shift are sufficient for the manufacturing process and the transfer of the product made to the storage tanks and, in addition, the feeding of raw materials, potassium salts and possibly colloidal clay, to the plant.

At any time, the above described production plant is able to manufacture any complex liquid fertilizer formulation requested by the market. However, in view of the structure of the distribution network which was adopted and will be described later, the number of formulations made by the plant is very limited.

Distribution of liquid fertilizers "PRAYSOL"

If liquid fertilizers are advantageous from the viewpoint of cost of labour and handling in the factory as compared to conventional solid fertilizers, the design of the distribution network to take them to the consumer needs careful consideration. Indeed, since the nutrient concentration, at least for most liquid fertilizer formulations when they are used, are in general somewhat lower than the corresponding formulations of solid fertilizers for the same ratios, the transport costs to the farm might, if one is not careful, prove prohibitive. It is then for the purpose of bringing liquid fertilizers to the field as cheaply as possible that the PRAYSOL distribution system was studied, designed and finally implemented. It immediately appeared that the most appropriate way of reducing distribution costs would be to take liquid fertilizers, in as concentrated a form as possible, to a site very near the field or the farm, e.g. to reduce to a minimum the transport of the sometimes low-grade compound formulations actually used.

To achieve that goal it was decided that the factory would only supply or manufacture so-called basic formulation, each of which supplying mainly, in the highest possible concentration, one of the three nutrients N, P and K. These products would be taken to a place near the application site and would enable, by simple physical mixing in adequate proportions, to make the complete range of ratios required by the farmer.

A thorough investigation was conducted to determine the structure and place of the final distribution site to supply the field.

After having discarded as a "standard solution" the possibility of liquid fertilizer storage on the farm, considering that for 100 hectare farm the minimum storage capacity would be 25,000 l which, on one hand would require substantial investments in tanks and handling equipment and on the other hand would not provide sufficient capacity to ensure that fertilizers are available when needed, especially during seasonal peaks when daily consumption of more than 25,000 l is usual. In addition, in the case under study, namely Belgian agriculture, mainly concentrated in the Southern part of the country, the establisment of a relay station for the storage of fertilizers between the factory and the final application point is not justified, which would mean, in the case of farm storage, that the factory would have to have available a high number of tank cars to ensure a prompt supply.

In addition, it was felt more economical that the farmer who, at present, has to invest in equipment for spraying pesticides, in view of the ever increasing frequency of spraying herbicides, fungicides and insecticides, reserves the capital he could spend in tanks for buying a sprayer which he could use for applying liquid fertilizers.

With this in mind, a systematic investigation in the main agricultural areas was undertaken both qualitatively and quantitatively. In addition, different enquiries were made among progressive farmers together with a number of trials on variable areas, bu never less than a minimum of 5 hectares. This survey finally resulted in the decision to establish in several stages "distribution stations" located first in the areas offering a high fertilizer consumption potential.

These stations were designed so that they could store each basic liquid fertilizer formulation N-P and K (clear liquid or suspension) in tanks with 65,000 l capacity, usually six of them ; in addition, they include a 5 m^3 water tank and a calibrated mixing tank of 6 m^3 capacity and the loading and unloading pump required. These stations are managed by a person independent from the factory who usually leases the land needed for the station and serves an area of about 7 km radius.

There are 40 of them at present and this number is increasing every year to respond to the market requirements.

In addition to the distribution equipment including all the stations and tank cars to supply them from the production works, a number of contracting "merchants" visit customers.

These contracts guarantee that the merchant is :

- at the farmer's disposal to recommend the most suitable fertilizer within a given fertilization programme
- equipped with the vehicles necessary to take the liquid compound fertilizer "PRAYSOL" to the field, if farm delivery is requested
- by arrangement with spreading contractors, if one chooses, the solution liquid compound fertilizers "PRAYSOL" can be applied.

In addition, an agricultural and technical service, belonging to the "PRAYSOL" Division which manages the whole distribution, including a number of agronomists and agricultural technicians, deals with all problems of technical assistance and recommendation when the farmer needs it or when a visit is made to him according to a fixed programme. The recommendations are either agricultural or technical.

The publication of a technical guide, offered to farmers and continuously updated, puts him in a position to find easily most answers to his questions regarding possibilities offered by the integral liquid fertilization system PRAYSOL in relation to the type and the size of his farm.

In practice, the operation of that system can be summarized as follows :

- the producer makes the highly concentrated basic formulations and supplies the distribution stations with them by means of large vehicles.

The PRAYSOL distribution stations ensure fertilizer storage in the most suitable conditions and, because of their location, the farmer need not worry about his supply.

In addition, these stations are known as being able to make any type of formulation just prior to delivery, which allows the farmer not only to adjust his dressings according to his agricultural conditions but also to readjust them if the conditions change before fertilizer application.

Finally the proximity of the application site allows a quick and economical transport of fertilizer from the station to the field with nurse tanks.

The experience showed that the transport time from the station to the field can be favourably compared to the handling time at the farm (possible mixing and locating) plus the transport time from the farm to the field.

The farmer places an order to the merchant, takes delivery of the fertilizer when he requires it at the nearest station and, for that purpose, receives containers on trailors, or has fertilizers delivered by the carrier, or has fertilizer applied by a contractor of his choice.

After the description of the system let us consider the situation regarding basic, then final formulations and ratios.

The so-called basic formulations are those made at the factory, with a fairly high concentration in one of the nutrients N, P and K, and final formulations are those made in the distribution station as a result of the physical mixture of two or three basic formulations with a view to field application.

Before discussing these formulations, it is important to define the method of expressing grades for liquid fertilizers, mainly adopted in Europe ; indeed, while the nutrient content of solid fertilizers is expressed in terms of weight, e.g. for 100 kg, the composition of liquid fertilizers is usually expressed in terms of volume, e.g. in kg of nutrient per 100 l although, in the case of Belgium, legislation compels us to sell on the weight basis.

This method of expressing contents by volume results from the very nature of liquid fertilizers and their method of utilization. Since their specific weight exceeds 1 (1.2-1.5 according to formulation) the figures expressing the nutrient contents per 100 l exceed the corresponding figures expressed per 100 kg.

Basic formulations

There are at present 3 such formulations instead of 4 initially :

- Nitrogen or urea nitrate solution, purchased outside. It contains 39 kg/ 100 l N including 25 % NO_3-N, 25 % NH_4-N and 50 % urea N. It is a clear and colorless solution supplying N.
- NP ammonium polyphosphate solution made at Prayon works. It contains 15 kg NH_4-N and 50 kg P_2O_5 per 100 l with at least 60 % of total P_2O_5 in polyphosphate form. It is a clear greenish solution supplying mainly P.
- The basic suspension made at Prayon using ammonium polyphosphate and potassium chloride or sulphate. It contains 4.5 kg NH_4-N, 15 kg P_2O_5 and 45 kg K_2O per 100 l. It is an opaque liquid containing fine solid particles and highly viscous. The basic suspension supplies mainly K.

As above stated, initially a fourth basic formulation was made in the factory. Indeed, at the same time as the basic formulation 4.5/15/45, a clear basic liquid fertilizer 1.5/5/15 was marketed. It was a clear solution containing 1.5 kg NH_4-N, 5 kg P_2O_5 and 15 kg K_2O per 100 l which was the main nutrient supplied. This formulation enabled farmers with no suspension fertilizer equipment to choose the integral liquid fertilization system.

However, the present situation of the Belgian market is such that, on the one hand the amounts of potash applied per hectare mean handling enormous bulks of clear NPK liquid fertilizer per hectare of arable land and on the other hand most farmers who chose to apply liquid fertilizers are equipped with suspension applicators. If not, spreading contractors have this equipment. Under these conditions, this formulation was felt unnecessary and was deleted.

It should be stated that basic formulations and, in particular suspensions in the autumn, can be applied as such.

Characteristics of basic formulations

CONTENT						N form by weight (kgs to 100 kgs)		
Volume kg/100 l			Weight kg/100 kg			Amm.	Nitr.	Urea
N	P_2O_5	K_2O	N	P_2O_5	K_2O			
39	0	0	30	0	0	7,40	7,40	15,20
15	50	0	10,70	35,60	0	10,70		
4,5	15	45	3,0	10,00	30,00	3,00		

Final formulations

These formulations, listed hereunder, are made at the distribution station before they are sent to the field, e.g. in fact shortly before spreading itself. There are NP and NPK fertilizers resulting from the mixture in volume of two or three basic formulations stored at the station. In a calibrated 6000 l mixing tank, the manager of the distribution station feeds in the ingredients normally with a pump according to predetermined pattern, 100 l at a time for each formulation ; as soon as the ingredients and possibly the water needed are introduced, he makes the mixture uniform by circulating it in a closed-circuit into the tank and then the loading of the farmer's containers, or possibly the applicators.

The time for manufacturing 6000 l of mixture, including the addition of basic ingredients in the mixing tank and loading containers never exceeds 30 min.

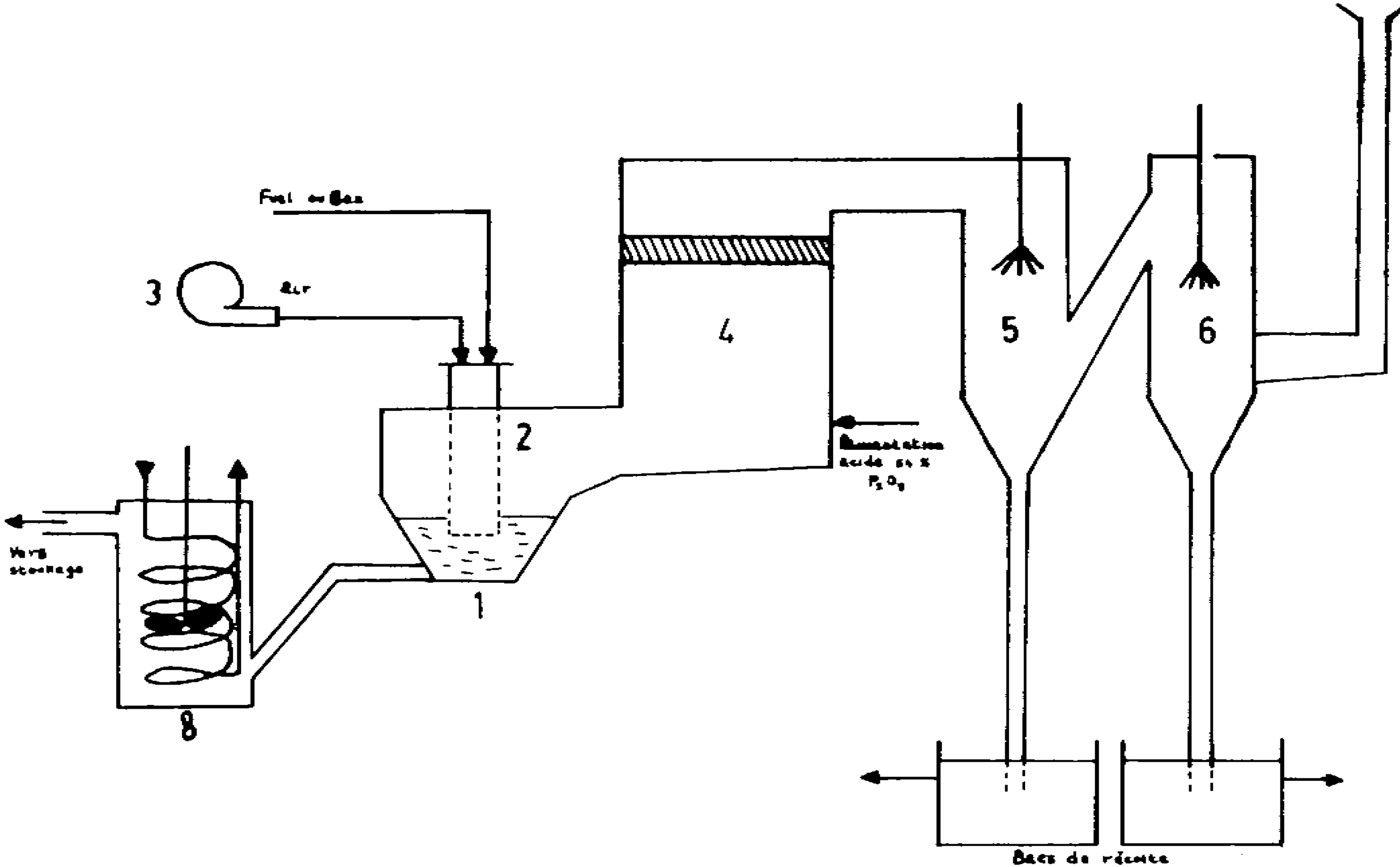
In some cases of regions using largely the same formulation, it is worth, in order to reduce the number of mixtures and, hence, the load of the distribution station at the time of the seasonal peak, having in one tank of the station a substantial amount of the formulation wanted. For that purpose the final formulations concerned , which are stored for a fairly long time, are made in the works in order to give them good storage properties which they do not have when made at the distribution station. It is obvious, owing to the transport cost involved, that this procedure is applicable only to higher concentrated formulation.

Comprehensive list of NP and NPK final formulations

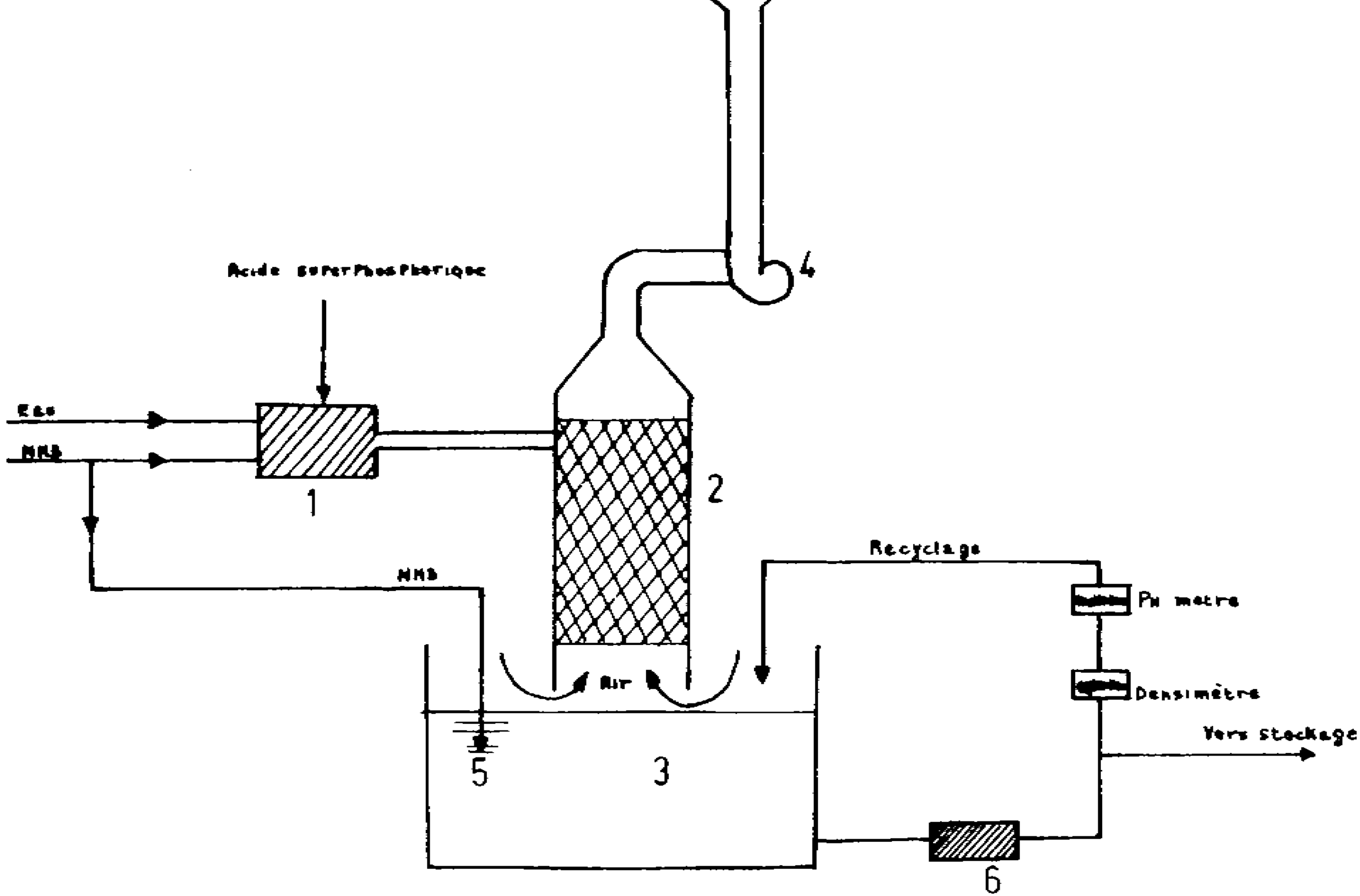
CONTENT						N form, kg/100 kg		
Volume kg/100 l			Weight kg/100 kg			Amm.	Nitr.	Urea
N	P_2O_5	K_2O	N	P_2O_5	K_2O			
20	39	0	14,50	28,25	0	9.95	1.50	3.05
22	33	0	16,20	24,25	0	9,50	2,20	4,50
26	26	0	19,25	19.25	0	10,10	2.30	6,85
29	20	0	21.65	14.95	0	8.70	4.25	8,70
30	15	0	22,75	11.40	0	7.95	4.85	9.95
32	14	0	24,10	10.55	0	8.35	5.15	10.60
33	11	0	25.05	8.35	0	8.10	5.55	11,40
34	9	0	25.90	6.85	0	7.90	5.90	12.10
16.5	20	30	10.15	12.70	19.05	5.40	1.60	3.15
5	17	42	3.35	11.40	28.15	3.35	–	–
6	13	39	4.45	8.95	26.85	3.10	0.50	0.85
6	20	38	4,05	13.50	25.65	4.05	–	–
7	15	38	4.75	10.25	25.90	3.40	0.50	0.85
8	17	35	5,50	11.70	24,05	4.00	0.50	1.00
9	12	36	6.25	8.35	25.00	3.45	0.90	1.90
10	20	30	6.95	13.90	20.90	4.85	0.70	1.40
11	11	33	7.70	7.70	23.15	3.65	1.35	2.70
11	22	27	7.70	15.35	18.85	5.45	0.80	1.45
12	18	29	8,30	12.50	20.10	4.90	1.10	2.30
12	24	24	8.45	16.85	16,85	5.90	0.85	1.70
13	19	26	9,10	13.30	18.20	5,25	1.25	2.60
14	14	28	9.80	9,80	19.70	4,60	1.70	3.50
15	10	25	10.85	7,20	18.05	4.30	2.20	4.35
16	16	24	11.30	11.30	16.90	5.35	1.95	4,00
16	25	16	11.45	17.90	11.45	6.90	1.50	3,05
17	13	25	12,00	9,15	17.65	5.00	2.30	4.70
18	18	18	13.00	13.00	13.00	6.20	2.25	4,55
21	10	21	15.30	7,30	15.30	5.45	3.30	6.55
16	20	30(x)	10,15	12.70	19.05(x)	5.40	1.60	3.15

(x) based on potassium sulphate.

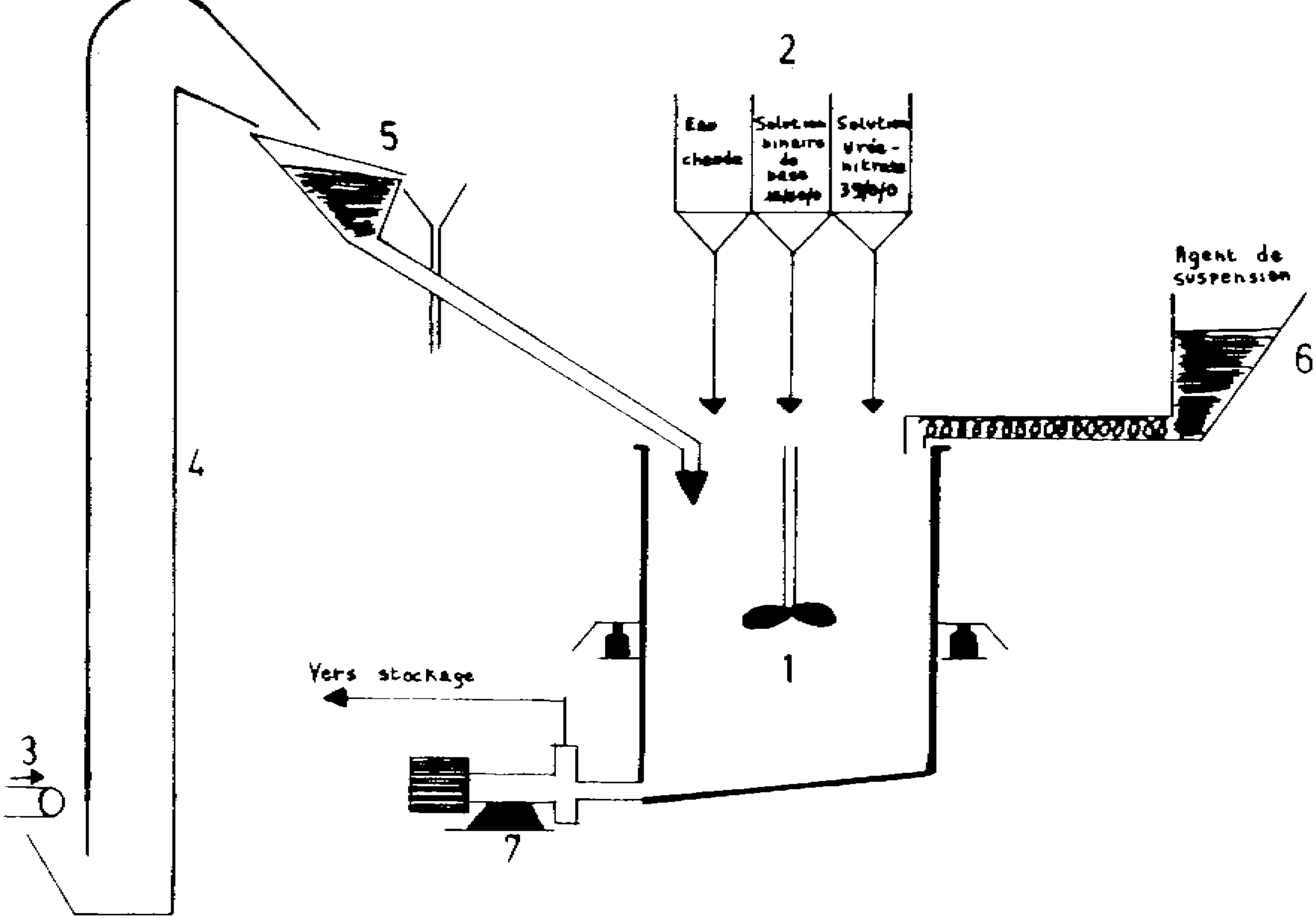
All these formulations are based on ammonium phosphate "POLYPRAY" containing P_2O_5 in the form of polyphosphate.



I.- FLOWSHEET OF SUPERPHOSPHORIC MANUFACTURE



II. FLOWSHEET OF 15-15-0 NP SOLUTION MANUFACTURE



I. FLOWSHEET OF LIQUID FERTILIZER MANUFACTURE