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KEMIRA NUTRIENTS RECOVERY SYSTEM - AN EFFICIENT METHOD OF ELIMINATING AIR POLLUTION IN NPK FERTILIZER PLANTS

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ABSTRACT

In the 1980's Kemira has realized an extensive program aiming at air pollution control at its compound fertilizer plants. The reasons for undertaking such a program were on one hand the sharp increase in the output of the fertilizer plants and the subsequent increase in the emissions in the air. On the other hand, the company wished to get prepared for the new air pollution control legislation that was to take force in the country.

The company has also invested in research and development by means of which information has been acquired on the formation of emissions in the fertilizer process and the methods of reducing them. The results of this work have been successfully combined with the long experience in the operation of fertilizer plants. As a result, Kemira has developed a nutrients recovery process for fertilizer plants with which the valuable nutrients in the waste gases can be returned to the production process in a concentrated form.

This method prevents the formation of waste waters harmful to the watercourses, in addition to which it allows the utilization of external nutrients-containing waters as make-up water of the scrubbing waters without extra costs. The system is in use at all of Kemira's fertilizer plants.

1 INTRODUCTION

The compound fertilizer production of Kemira is based on a process developed by the company itself. The process offers several technical and economical advantages, but it also imposes great requirements on the pollution control.

Our company has realized an extensive air pollution control program at its own fertilizer plants. This presentation concentrates on viewing the reasons that led to undertaking such a program and its carrying through. Some practical experiences of the new investments are also considered.

2 RULES AND REGULATIONS GOVERNING FERTILIZER PLANTS

2.1 General

In Finland pollution control is regulated by means of special legislation concerning

- water pollution control	law on water protection 1962
- air pollution control:	law on air protection 1982
- waste control:	law on waste management 1978

The most important authorities responsible for pollution control are:
- Ministry for the Environment
- National Board of Waters
- County Adminstrative Boards
- District bodies of the National Board of Waters
- Municipal authorities responsible for pollution control.

2.2 Waste waters

The law on water pollution control in Finland presupposes that every company has a valid permit for effluent discharge. The permit is for a certain period only and is valid for 4 to 7 years in course of which period the company has to apply for a new permit. The authority granting the permits is the Water Court. In the conditions e.g. the following issues are specified:

- maximum amounts of various impurities in the waste waters

- an obligation to control the amounts of waste waters, their quality and effects on the watercourses, also including an obligation to report to the authorities

- Liability for damages to the injured party

The permit is for the whole plant complex, which in Kemira's case often includes several installments such as compound fertilizer plant, nitric acid plant, phosphoric acid plant, power station, etc.

The conditions take into account the vulnerability of the watercourses where the waters are led, the operation of the plant and other such conditions. The advantages and disadvantages from the point of view of the society are also evaluated. In any case, the production plant shall indemnify the losses to those who have suffered damage.

The permits concerning the discharge of waste waters from the fertilizer plants of our company usually include limitations to the loads of phosphorus. For instance, the permit of the Siilinjärvi Works located in the lake district in Central Finland limits the allowable discharge of phosphorus to 8 kg/d, which figure also includes the effluent discharge load of the phosphate mine. In this case phosphorus is a minor factor from the point of view of the receiving watercourse, in other words, a small increase in the amount of phosphorus led to the watercourse causes eutrophication through increasing growth of algae.

2.3 Waste gases

According to the legislation on air pollution control in Finland, the companies shall give to the authorities of the various counties a detailed specification of the emissions in the atmosphere, their spreading to the surroundings and effect on the nature. Such a statement concerning fertilizer plants had to be submitted by 31 March 1985. In Finland there are no nation-wide norms common to the fertilizer industry. Instead, on the basis of the above statement the County Administrative Board makes a decision by which it confirms the allowed emission level for each plant separately. The decision may also include a scheduled programme for the reduction of the emissions or other obligations. So far no decisions concerning fertilizer plants have been made, due to the work load in the handling of the statements. However, Kemira has by voluntary means been trying to fix the air pollution control at its plants to a level which we believe will be satisfactory to the authorities.

3 MEASURES TAKEN BY KEMIRA FOR AIR POLLUTION CONTROL

3.1 Background

During the past ten years the production figures of Kemira's fertilizer plants have risen sharply. This has been due to efficient debottlenecking and the adoption of a new and efficient reactor system developed by our company. Thus the production capacity of our fertilizer plants is 2 to 3-fold compared to the original design capacity, as can be seen in the table below.

Table 1

Location of plant	Year of constr.	Original capacity t/d	Present capacity t/d
Oulu	1957	200	700
Harjavalta	1964	200	700
Uusikaupunki I	1965	300	950
Uusikaupunki II	1967	600	1200
Kokkola	1970	400	1250
Siilinjärvi	1972	700	1600

The increase in production also led to a sharp increase in the emissions of the plants.

Due to the harsh climatic conditions prevailing in the Scandinavian countries in winter, the forests consisting mainly of coniferous trees are exceptionally susceptible to impurities in the air. Damage to the vegetation in the surroundings of the plants often gives rise to strong reactions on the part of forest owners, the people living in the neighbourhood as well as the mass media. These reactions can easily harm the company image in the long run. One must not forget either the nutrient losses due to emissions in the atmosphere. All these factors together as well as the new air pollution control legislation in Finland forced our company to seriously study the situation and the concrete measures to be taken.

3.2 Research with the aim of reducing emissions

3.2.1 Control measurements

The emission levels at our fertilizer plants have already long been followed up systematically. A team for measuring of emissions has been working at our Research Centre since the 1970's for determining the emissions at all of our plants. The measuring devices are carried by a caravan to facilitate the moving of the measuring team from one location to another.

The emissions from the stacks of all of Kemira's fertilizer plants have been controlled for several years regularly by means of continuously operating sampling devices. The samples gathered are analysed and on the basis of these measurements made at regular intervals the emission levels and their development at all of our fertilizer plants have well been followed up from the beginning. This unique information material gave a good basis for making an analysis of the situation and for the planning of remedial measures.

3.2.2 Research and development

A typical feature of the fertilizer industry is that the waste gases contain micro-particles or aerosols. If the plant is located near a population centre the bluish mist that is formed in the process is regarded as a nuisance due to its visibility.

In 1982 Kemira Oy launched an extensive research project with the aim of acquiring information on the aerosols in the waste gases, their amounts, particle size distribution, chemical composition, mechanisms of formation and the methods of reducing them.

The research work was preceded by a gallup in which the views of the operation personnel at the plants were asked concerning the possible reasons for the formation of the bluish mist.

A suitable measuring system of the aerosols had to be found and further developed. Equipment with which the aerosol content of the humid and hot gases could be measured, and with which the particle size, composition of the aerosols as well as the amounts of gaseous impurities were determined had to be found.

The measuring system (see Fig. 1) consists of a suction pipe which can be heated, through which the sample is sucked via three cyclones in a series, at a temperature corresponding to that of the process. The cyclones are located in an insulated box heated by means of electric resistance. The gas leaving the cyclones is led into absorption bottles via a condensing vessel. Thus the aerosols are divided into three fractions which are weighed after which a chemical analysis is made. The amounts of gaseous compounds can be determined from the chemical analyses of the absorption liquids.

The D_{50} values of the cyclones used in the measurements were 2 um, 0.7 um and 0.3 um.

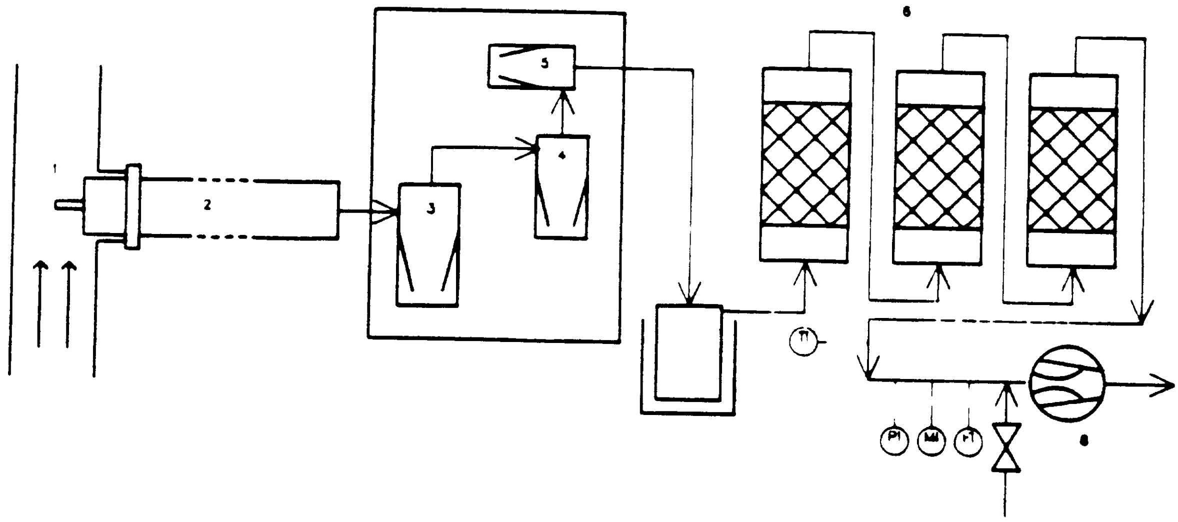

Figure 1: Measuring system

An extensive measuring programme on the process emissions was carried out at Kemira's Siilinjärvi fertilizer plant by means of the equipment developed. Regression analysis by means of a computer was used to find out the correlations between the process variables and the amounts of aerosols.

The information gathered from the measurements has been successfully utilized in making improvements in the processes and in the engineering of new scrubber systems.

Besides reactor and granulation models of fertilizer plants, Kemira Engineering has also made a computer-based model for the process calculations of the gas scrubbing system. It enables the rapid calculation of the material and energy balances and scrubbing efficiency of a scrubbing system with several scrubbing stages, by various input data and different scrubber types. The adjustments of the model are based on measurements carried out separately at each plant.

3.3 Investments in air pollution control

In the 1980's our fertilizer plants have been vigorously modernized. In most cases the first impulse for the modernization has been given by the unsatisfactory operation of the gas purification equipment and the consequent high level of emissions and losses of nutrients. However, modernization aiming at the improvement of air pollution control is such an extensive measure that other objectives improving the feasibility have also been realized in connection with the modernization, such as:

- raising of the automation level
- increasing of the economy and reliability of operation
- replacement of worn-out process equipment by new ones
- increasing the efficiency of nutrients recovery

In this way the investments made in improving pollution control have also proven to be investments in productivity.

Kemira has carried out the following improvements in air pollution control at its fertilizer plants:

Oulu fertilizer plant, 1982

- Modernization of fertilizer reactors and scrubbing of reaction gases

Harjavalta fertilizer plant, 1983

- Complete modernization of the plant including e.g. the construction of fertilizer reactors, improving of dust separation, and modernization of wet scrubbing section of reaction and drying gases.

Uusikaupunki fertilizer plant I, 1984

- Complete modernization of the plant including e.g. the construction of fertilizer reactors, improving of dust separation, modernization of wet scrubbing section of reaction and drying gases, and raising of the automation level.

Kokkola fertilizer plant, 1984

- Modernization of the scrubbing sector of drying gases.

Uusikaupunki fertilizer plant II, 1984

- Modernization of the scrubbing sector of drying gases

Siilinjärvi fertilizer plant, 1985, 1986

- Complete modernization of the wet scrubbing system of exit gases by stages so that the first stage comprised the modernization of the reaction gas scrubbers and the second stage that of the drying gas scrubbers.

4 REALIZATION OF INVESTMENT PLANS

4.1 Preliminary planning

The projects described above were realized as co-operation projects between Kemira Engineering and the local organization of each plant. In this way the years of practical operation experiences have been successfully combined with research and development.

The initiator in investments of this kind is the local plant management which appoints a team to study the case. The team can consist e.g. of the following persons:
- plant engineer and operation technician
- technical experts from the plant and from Kemira Engineering

The preliminary work includes the creation of various models for the realization of the improvements whereafter a more detailed technical and economical comparison is made for the most feasible ones of them. The aim of this comparison is to evaluate the investment and operation costs of each method, the purification result to be obtained as well as other advantages and disadvantages.

The team presents the various alternatives and recommendations for the ways of realization to the management. A final investment proposition with cost and profit calculations and time schedules is made on the basis of the approved alternative. The management responsible for the investments in the Fertilizer Division makes a list of priority for the investments inside the division. The final power of decision in investments of this size rests with the Board of Directors and the Supervisory Board of Kemira.

4.2 Implementation

The investment plan is carried through in form of a project in accordance with a specified time schedule. The project organization consists of a project manager responsible for the project, and a project team comprising key personnel representing the various fields of engineering.

The engineering phase is the very basis of successful modernization. It is therefore of vital importance that the operation personnel of the plant can participate in the planning and give their opinions of the plans. In this way the plant can be finalized up to the least detail taking into account the guidelines set by those operating it. The operation personnel becomes better motivated and gets better familiar with the new equipment. At the same time the advangtages of the extensive experience of the operators can be utilized and many inconveniences are avoided in the commissioning phase of the plant. Kemira Engineering's Intergraph CAD system has successfully been utilized for the detail engineering of the various investments plans.

The installation phase is the most critical phase in the implementation. The installation period has to be chosen in a way that the interruption in the production causes as small economical losses as possible. For this reason the shutdown period has to be minimized which leads to a minute-by-minute schedule. As appropriate, preparatory works for the installation should be made when the plant is in operation before the actual shut-down and, on the other hand, finalizing works can be made after the re-start of the plant.

5 SPECIAL REQUIREMENTS IMPOSED ON THE GAS SCRUBBING SYSTEMS OF FERTILIZER PLANTS

Both gaseous and particle emissions are released in the production process of compound fertilizers, such as:

- ammonia
- dust and aerosols
- fluorides
- nitrogen oxides

The scrubber types and purification conditions have to be chosen in a way to take into consideration the special features and requirements of each impurity component.

On the other hand the amount of emissions is dependent on the process conditions which vary to a great extent between the various fertilizer grades produced, depending on the raw materials used and their mixing ratios.

In addition to the amounts of impurities, also the amounts of gases fluctuate. Thus the gas purification system shall be capable of coping with rapid fluctuations in load.

One important requirement is that the nutrients-containing wash waters can be returned from the gas purification section back to the process. However, this shall be done in an as concentrated form as possible, to avoid evaporation of excess water in the fertilizer process itself.

The scrubber system shall be equipped with reliable measuring and adjustment devices well suited to the circumstances. Efficient instrumentation and especially trouble-free pH regulation form the basis of a well functioning scrubber system leaving the operation personnel time to control the production process itself.

In addition to the above, there are many other factors which shall also be taken into account in the engineering such as e.g. a minor tendency to clogging and other troubles in the operation, the investment and operation costs and ease of maintenance and control.

6 KEMIRA NPK PROCESS AND RECOVERY OF ESCAPED NUTRIENTS

6.1 Basic features

A simple and reliably operating reactor system and great flexibility in regard to both the raw materials and the grades to be produced are the features typical of the NPK process developed by Kemira. The Kemira NPK process enables the production of various fertilizer grades, from pure nitrogen fertilizers up to grades containing large amounts of phosphorus and potassium (potassium chloride or potassium sulphate). Some examples of the fertilizer grades that can be produced by this method are listed below.

26- 0- 0	15-15-15
30-10- 0	12-30-10
23-23- 0	12-24-12
20-10-10	10-20-20
16-16-16	0-20-20

The Kemira NPK process is in use at Kemira's six fertilizer plants in Finland. The method has been licenced to Superfos A/S in Denmark and to Rashtriya Fertilizers & Chemicals Co. in India.

Besides flexibility, another features typical of the Kemira fertilizer process are both the low water content of the slurry that is led to the drying section, which means advantages in regard to the drying capacity and energy consumption, and a closed scrubbing liquid circulation. These necessitate good control of the water balance of the fertilizer plant.

The starting point in the realization of a nutrients recovery system is that the circulation of the gas scrubbing waters from one washing stage to another takes place in a certain sequence, when the waste energy in the emission gases can be utilized for the concentration of the washing liquids. For the recovery of ammonia, acid is added to the washing liquids so that the pH of the washing liquid is kept on a level sufficiently low from the point of view of the absorption of ammonia. Only a limited amount of make-up water is led to the scrubbers thus avoiding the dilution of the washing liquids.

The scrubber types are chosen in a way to reach an optimal purification result in regard to the various impurity components to be separated, at optimal costs. The scrubber types shall also be well adapted to the difficult process conditions.

6.2 Recycling of gas scrubbing waters in a concentrated form

Gas scrubbing in Kemira's compound fertilizer plants is realized as a form of a multi-stage countercurrent wash as shown in Annex 1. The reactor exit gases are treated in their own washing lines in an one- or multi-stage wash and the drying gases in their own one- or multi-stage wash. In order to intensify the absorption of ammonia, sulphuric acid, phosphoric acid or nitric acid is added to each washing stage. Nutrients-containing water collected in the floor sump of the plant or pure water, if necessary, is used as additional water. The additional water is led into the cleanest washing stage, i.e. in this case into the latter washing stage of the reactor gases. From there the scrubbing water is further led into the first washing stage of the reactor gases and finally to the drying gas scrubber.

In this way, as the scrubbing water flows from one stage to another, its content of nutrient salts gradually increases. No significant evaporation of water into the reactor gases takes place, as these gases are almost saturated with water vapour. On the other hand, the humidity of the gases leaving the drying drum is quite low, so that significant evaporation and concentration takes place in the drying gas scrubber. This is a prerequisite for the economic recirculation of the nutrients to the reactors by means of a minimum quantity of water.

A separate device for solid matter can be installed in connection with the washing liquid circulation of the drying gases, such as e.g. a clarifier, filter or centrifuge, where a secondary flow of washing liquid is led.

Insoluble solid matter such as crystallizing ammonia salts and fertilizer dust washed in the scrubbers are separated from the washing liquid. The washing liquid free from solid matter returns to the scrubber and the washing liquid slurry containing large amounts of solid matter is returned back to the fertilizer reactors. By means of this arrangement the quality of the scrubbing liquid circulating in the scrubber is improved, from the point of view of the operation of the scrubber. Moreover, the nutrient salt concentration of the scrubbing liquid returned into the process is raised. Thus the water balance of the reactors remains stable, even if the water content of the fertilizer slurry were kept high in order to reduce the drying costs.

7 PRACTICAL EXPERIENCES

In most cases the starting up of the new gas scrubbing systems at Kemira's fertilizer plants has taken place "at the push of a button" and the objectives set for the projects have been reached.

The most interesting case was the start-up of the Uusikaupunki fertilizer plant I after an extensive modernization work. In this case the operation personnel of the plant shunned at first the new digital technology. Thus, during the first month of production after the start-up several interruptions occurred in the operation. The reason for these interruptions was inexperience with the new equipment and instrumentation and the subsequent different reactions in a changed situation. After these initial difficulties smooth and steady operation was reached so that in 1985 the plant reached a new record in the production surpassing the previous record by 18.1 %. In this case the increase in the capacity came as a non-predicted advantage in connection with an investment aiming at raising the level of pollution control.

There is practically no need for cleaning of the scrubbers nor the subsequent need for shut-down, which feature has remarkably improved the rate of operation of the plants.

The purification result has also been steady and of a very high standard. The clearly improved quality of the waste gases can be seen both in the form of recovery of the vegetation and as positive reactions on part of the people living in the neighbourhood of the plants.

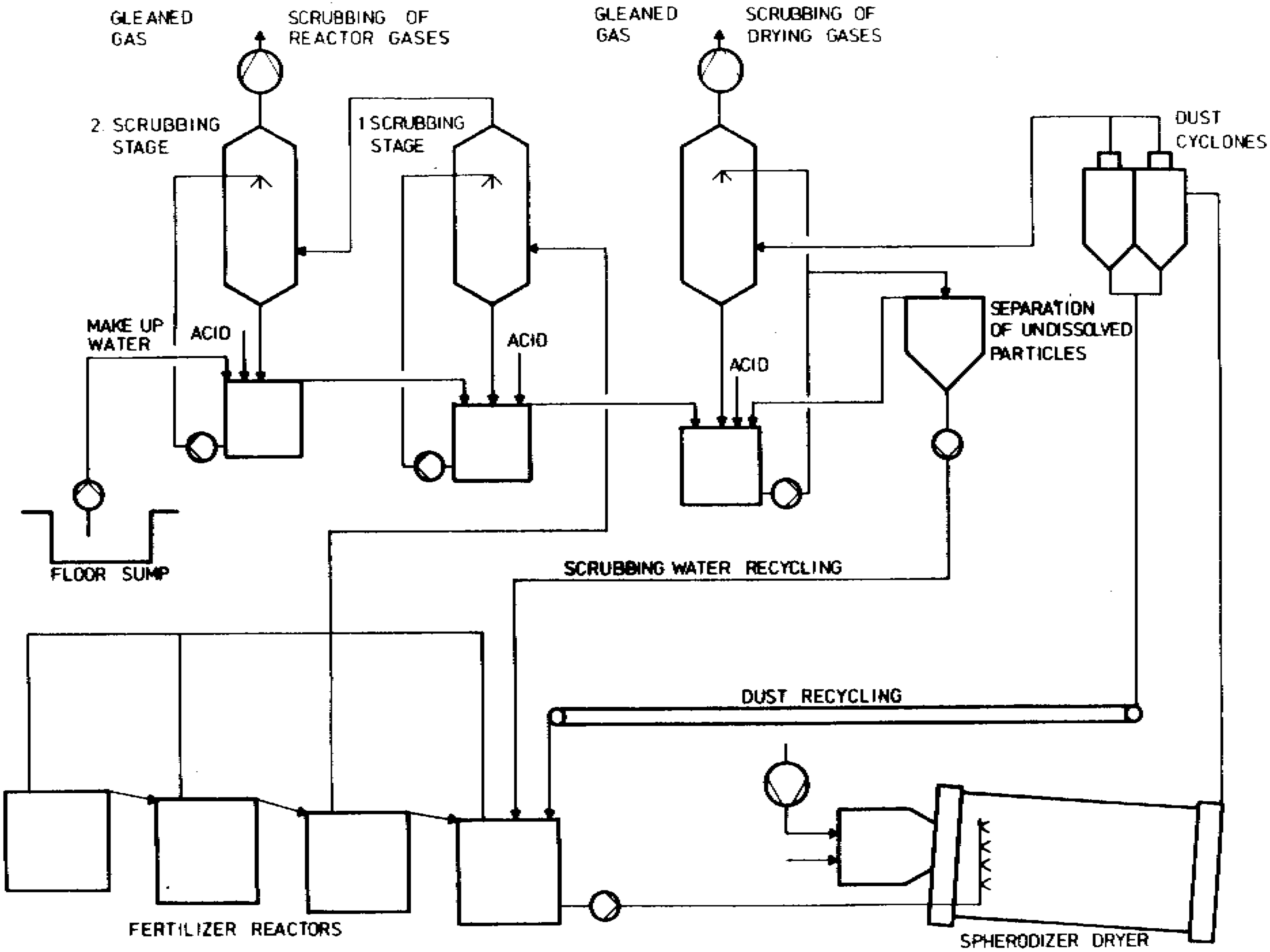

FIG. 1 CIRCULATION SEQUENCE OF SCRUBBING LIQUIDS

TA/80/16 Kemira nutrients recovery system - An efficient method of eliminating air pollution in NPK fertilizer plants by P. Lammi, Kemira Oy, Finland

DISCUSSION : (Rapporteurs Messrs A. Bourgot & M. Sart, Prayon-Rupel, Belgium)

Q - Mr. M. SEDIEZ, PEC Engineering, France

You mentioned "dust and aerosols" emitted from the stack. How do you measure dust and aerosols? Do you have independent measuring devices and what are they?

A - My paper describes the measuring device used for aerosols; it is a particular system specially designed for our process. Generally dust and aerosol sampling is done with our system in the stack gases, but dust and aerosols are not separated for analysis. The first stage of the sampling system is a glass fiber filter, the second a condensing vessel followed by absorption bottles for gaseous compounds. The evaluation of the amount of dust in the gases takes also account of the dust retained in the filter and we also take account of the evaporation or condensation residue.

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

The last slide in your presentation shows kg/h of dust, aerosols etc... What is the amount of gas in m3/h?

A - 200,000 m3/h.

Q - Mr. M. SIMOGLOU, PFI, Greece

Could you please distinguish which is the dominant means for aerosol elimination i.e. process parameters adjustment or new scrubbing system installation?

What is the predominant factor for aerosol elimination?

Please give some examples of the influence of process parameters in the aerosol formation?

A - In our aerosol research project, we found that the amount of aerosols strongly depends on process conditions and we determined the main reasons of the aerosol production. The amount of aerosols also very much depends on the quality of the products were make.

Obviously, it is always possible to adjust the operational parameters, but often at a high cost for some processes. Thus, to answer, we try to eliminate aerosols with our very efficient multistage gas scrubbing system. There are two parts, which ensure a good aerosol abatement: the first is the Venturi, the second is the condensation which can be achieved without affecting the overall plant water balance.

We found that, in our conditions, aerosols are often made of ammonium nitrate coming from the reactor and that the reactor temperature and the control of the nitric acid used play a very important part in the amount of aerosols formed.

Q - Mr. B. PERSSON, Supra, Sweden

What is the energy consumption for the nutrient recovery systems in a NPK plant?

A - I do not remember the accurate figure. It finally depends on the desired degree of elimination of aerosols; consumption varies from 5 to 15 kWh/t product (pumps, etc... incl.). It is difficult to distinguish if one includes cyclones etc... The figures indicated are only within a wide range.

Q - Mr. J.M. BIRBEBAEK, Superfos, Denmark

1. What type of scrubbing equipment have your preferred in your plants?

2. What is your emission from the wet and the dry sections mg/m3?

3. What is the power consumption in kWh/m3 gas being scrubbed?

4. How is your equipment prepared for easy modification in order to reduce emission even more than now.

A - I have no accurate figure, but, in general, 50% of the total emissions after scrubbing are due to the gases from the reactor, according to the compounds considered; these figures apply to ammonia and dust; for fluorine 80% come from the reactor and 90% for NOx.

We do not believe that the limits will be more stringent in the near future, but, if this is the case, the amount of steam should be slightly reduced. It is possible, since the last scrubbing stage is so efficient that there should not be much problem.

Q - Mr. M. BARLOY, SCPA, France

Are your pollution abatement objectives final? that is:

- Can the legislation force you to reduce pollution still further?
- In that case, could you achieve it in an acceptable economic way?

A - It is a delicate question; I do not think that the standards will become more drastic, in any case in Finland, where they are already quite drastic. However, the situation is not blocked and things can always change. The authorities do not presently seem to have a ready made strategy for atmospheric pollution; it is then very difficult to answer your question.

Q - Mr. N.W. KOLMEIJER, Windmill, Netherlands

The formation of relatively large quantities of aerosols is apparently inherent to the use of spherodizers. The concern about this pollution problem and the remedy came after the instalment of these granulator-driers. The abatement of an aerosol is usually done via the generation of large pressure drops and, consequently, at the cost of a considerable quantity of electricity.

If Kemira would have to start from scratch, would again spherodizers be selected or is a different system, e.g. conventional granulation, to be preferred?

A - I do not agree when you say that our problems arose with the use of spherodizers, since some of our plants include drum granulation (e.g. Kokkola) and, in another case, while spherodizer is used in other plants, at Uusikaupunki N° 2 and our atmospheric analyses showed that there was no aerosol in the drying gases.