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MODIFYING EXISTING DAP/NPK FERTILIZER PLANTS TO COMPLY WITH NEW ENVIRONMENTAL REGULATIONS

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RESUME

Beaucoup d'unités d'engrais ont été construites à une époque où les réglementations en matière d'environnement étaient moins strictes et par conséquent elles ne peuvent se conformer aux codes les plus récents. Il peut en résulter des pénalités importantes ou des limitations dans les opérations imposées sur l'unité. Il y a donc une forte incitation à moderniser une unité existante.

Les domaines types à problèmes sont : émissions de poussière, NH₃ et F et effluents liquides. Comme ces problèmes sont souvent liés, une amélioration spécifique peut parfois être réalisée par un petit nombre de modifications, comme le passage d'un système à boucle ouvert à un système à boucle fermé, des cyclones et des filtres de poussière améliorés, adaptés aux conditions opératoires.

Comme beaucoup de ces mesures comportent des appareils qui seraient changés dans un projet de réhabilitation ou de débridage, se conformer à de nouvelles réglementations n'entraîne pas nécessairement des coûts supplémentaires importants. En même temps, il est souvent possible de réduire les besoins en énergie pour la circulation des liquides et de l'air ce qui réduit ainsi les coûts opératoires.

Un certain nombre d'options de conception et de réalisation effectuées seront présentées dans cet exposé.



During the past 15 years fertilizer manufacturers have been able to increase the productivity of their granulation plants considerably. This has increased the potential magnitude of air and water pollution problems. A higher production rate not only increases the consumption of raw materials, at the same time the partial pressures of pollutants and correspondingly the emissions increase drastically. This is a result of the higher operating temperatures that result from the larger heat inputs (e.g. from the heats of reaction or crystallisation).

The same period has seen a growing interest in the topic of air and water pollution - by the government agencies responsible for monitoring effluents and by the general public. Regulations for emission control have been regularly updated and new concepts for environmental legislation are being discussed [1, 2]. In this environment it is therefore not amazing, that the number of publications relating fertilisers with environment can hardly be counted any more. Strategies for solving emission problems of fertiliser granulation plants are numerous. Some of these can only be implemented in new plants; others can be successfully utilised in plant modifications.

To systematically evaluate the countless emission control measures available for reducing plant emissions, we employ a 4-step approach. These steps, starting at the emission source, sequentially take into account larger parts of the plant, until the battery limit is reached:

Step 1: Reduce or avoid the formation of pollutants at the source.

This includes advanced, "environmentally friendly" designs of reactors such as:

- the "CARNIT" reaction system for ammonium nitrate,
- the "HOECHST" non-boiling neutraliser for nitrophosphate acids and improved equipment such as
- the "COMINCO" bulk flow heat exchanger that eliminates air for cooling and the inherent dust formation.

This type of pollution control is usually costly, highly efficient concerning energy but difficult to realise in plant modification projects. Nevertheless, in our opinion, the industry should pay more attention to these developments.

Step 2: Select process conditions and/or equipment to minimise emission of pollutants at the source.

An example is the use of a pipe reactor instead of a pre-neutraliser for the production of MAP. A pipe reactor, operating at an NH_4/PO_4 -mole ratio (M.R.) of approximately 1, produces only a fraction of the fluor-compounds of a pre-neutraliser, which due to solubility and viscosity reasons, operates at a M.R. of 0.7.

Step 3: Contain pollutants in a minimum of carrier.

This category includes such diverse measures as:

- installing indirect condensers rather than direct condensers , and
- minimisation of cooling air by using a two stage fluidized bed cooler with recycle of air. This air can subsequently be used for drying.

Step 4: Recover airborne pollutants.

Where possible in a dry form; where this is not possible as a scrubber effluent. Ideally all of the scrubber liquid produced is reintroduced into the process. This is dependent, amongst other factors, on the water - balance of the product.

Pollution problems in existing plants

Pollutants common to all NP/NPK fertiliser granulation plants are ammonia, fluorine compounds and fertiliser dust. When the reaction system of the plant includes a nitric attack or mixed acid attack section, nitrous oxides are produced as well. In addition, large amounts of water vapour are produced in the reactors, the granulator and in the drying drum. Although water vapour is not a noxious substance it has a pronounced effect on the efficiency of recovery of the noxious gaseous compounds.

In the following we would like to demonstrate our approach to typical problems confronting existing fertiliser plants. As the first step described above is usually only feasible when undertaking major revamps, we will therefore focus our presentation on the remaining three steps.

SOURCE	POLLUTANT	PARAMETER
Scrubber	Fluor compounds	Temperature, M.R.
Reactor (acidulation)	Nitrous oxides, Fluor compounds	Temperature, organic matter, type of acid
Neutraliser	Ammonia, Fluor compounds	Temperature, M.R.
Granulator	Ammonia, Nitrous oxides, Dust	Temperature, M.R., Granulation parameters
Drying drum	Ammonia, Dust	Temperature, M.R., Granulation parameters
Solids handling	Dust	Granulation parameters

Table 1: Sources and parameters affecting the various pollutants

1. Selecting process conditions to minimise emissions (Step 2)

Table 1 lists the sources of pollutants emitted by fertiliser plants and typical process parameters that directly affect the emissions.

1.1. The influence of partial pressure

At first glance it may be confusing to see that the scrubbing system listed as a source of fluoride emission. However, when phosphoric acid is used as the scrubbing medium and the M.R. in the scrubber is sufficiently low, the scrubber starts emitting fluoride compounds. A good example of this fact is reported by Boontje et. al. [3]. We duplicated this experience a few years ago.

The partial pressure of fluorine compounds is a function of the silica content of the acid, the M.R. and temperature. The effect of the mole ratio is quite enormous. The partial pressure of fluorine compounds over a mono - ammonium phosphate solution is less than 1% of that over phosphoric acid.

Nogueira and Choi [4] offer the following interesting explanation for mole ratios above 0.9: when the mole ratio is higher than 0.9, fluorine reacts with Fe and Al to form acid - insoluble compounds. This effectively removes the fluorine from the solution. Partial pressures of fluorine compounds decrease more or less uniformly over the whole range of the mole ratios. This is demonstrated by laboratory experiments mentioned by Boontje [3] for M.R.s below 0.6.

In general, the partial pressure of ammonia will increase with increasing M.R. and temperature.

1.2. The role of temperature

Temperature plays a dominating role in producing gaseous pollutants. This is easily explained by the effect of temperature on partial pressures and on the rates of reaction. When designing a plant, temperature considerations are of utmost importance. They include the choice of equipment as well as the organisation of this equipment within the plant.

A few examples may make this clearer.

In reactors for the digestion of phosphate rock, the acid used determines the amount of fluorine in the rock that is volatilised. When nitric acid is used, only about 1% of the fluorine in the rock enters into the gas phase. When sulphuric acid is used, as much as 40% of the fluorine present in the rock may be volatilised. These percentages are strongly dependent on the reactor temperature.

Let us compare the performance of pre-neutraliser and pipe reactor regarding emission of ammonia and fluorides, when producing ammoniated phosphate slurries with mole ratios between 0.6 - 1.5. For the production of MAP or a MAP-based NP/NPK fertiliser, we have to operate a pre-neutraliser, due to solubility and pumpability reasons, at a M.R. of 0.6 to 0.7 and temperatures of 115-120°C. Ammonia emissions at these temperatures are negligible but the fluorides are volatilised abundantly. The pipe reactor can operate at a M.R. of 1.0 - 1.10 and a temperature of 155-165°C; yet lose only 1-3% of the ammonia fed to the reactor. Despite the high temperature the losses of fluorine from the reactor are very moderate [5]. Actually, a somewhat higher ammonia slippage would be welcome to control the M.R. in the scrubbing section. When the product formulation allows a M.R. of 1.4 to 1.6, both reactor types hardly fume off fluorides. The ammonia losses from a pipe reactor are however, more than twice the losses from a pre-neutraliser [6].

At this point it should be noted, that the heat balance of the granulator - and therefore its operating temperature - is highly influenced by the type of neutraliser employed. With a pre-neutraliser the water vapour exits directly into the scrubbing system and the pre-neutralizer affects the granulator only by the amount of sensitive heat in the slurry. When a pipe reactor is used, the process steam exits through the granulator. This has a significant effect on the heat balance of the granulator: the higher partial pressure of water vapour in the air in contact with the mass of granules makes evaporation of water vapour from the granulator bed more difficult. As a result the operating temperature of the granulator rises. This causes the ammonia losses from the granulator to increase.

Therefore, in a DAP plant with a pipe reactor the ammonia losses from reactor and granulator combined can be about 20-25% of the incoming ammonia [6]. A conventional scrubbing system will have difficulties in efficiently recovering this ammonia. This is partly because the heat balance of the scrubbers is upset by the considerable amount of heat of reaction released during the chemical absorption of the ammonia.

An example of the effect of an unlucky organisation of equipment is the classic scrubber arrangement in American DAP plants - with their three primary scrubbers: the R/G (reactor/granulator) scrubber, the dryer scrubber and the C/E (cooler/equipment) scrubber (Figure 1).

All three scrubbers are of the Venturi type, usually with cyclonic separators. The R/G scrubber is fed with most of the ammonia and water vapour but only a relatively small amount of air. This forces the scrubber temperature up to a level of 85 to 90°C. The M.R. - between 0.6 and 0.75 - and the increase in M.R. in the scrubbers is too high for efficient ammonia scrubbing and too low to avoid the emission of fluorine compounds. With the improved productivities achieved in the 1980's and the increased awareness for emissions, the predictable reaction of the industry was to add a second tier of scrubbers, the so-called tail gas scrubbers (Figure 2).

The disadvantage of this solution is that the ammonia escaping from the primary scrubbers is lost, since most plants employ open circuits with pond water as scrubbing agent. However, pond water with its high amount of (silico) - fluorides is hardly the proper solvent to recover fluorine compounds from off gas. During the 1980's an elegant solution was proposed: the double mole scrubber (Figure 3) [7, 8]. A pre-scrubber with a low pressure loss and an independent liquid circulation is installed between the two ammonia sources and the R/G scrubber. The M.R. in this scrubber is between 1.2 and 1.5. Houghtaling reports a reduction in ammonia losses of 88% and F emissions reduced to one quarter of the original value. In spite of this impressive performance the US industry seems to be hesitant to embrace this environmentally sound and relatively cheap solution.

Some European designers have had a better hand in designing scrubbing systems. They feed the gases and vapours from reactor and granulator to a simple pipe scrubber. The off-gases of this scrubber are combined with the off-gas from the drying drum. Since this off-gas contains relatively little water vapour and a generous amount of air, the equilibrium temperature in the main scrubber is low - usually around 65°C. The circulation systems of pipe scrubber and main scrubber are combined, operating at a M.R. between 0.3 and 0.6. This is not optimal regarding recovery of fluorine compounds, but in the early 1980's we already had emissions of fluoride and ammonia below 10 mg/Nm³.

In UHDE's first pipe reactor plants we were taken by surprise by the high operating temperatures due to a faulty design and the consequent ammonia losses from pipe reactor and granulator [9]. We implemented the following solution (Figure 4):

- ventilate the granulator, using it as an evaporative cooler,
- separate the pipe scrubber circulation from that of the main scrubber. The pipe scrubber typically operates at 90 to 95°C, when DAP is produced, and at around 70°C, when the plant produces NP or NPK. The M.R. is kept in the range of 0.4-0.6.
- The main scrubber runs at very low P₂O₅ concentrations (10 to 15%) and we have found it advantageous to operate it at a M.R. of around or slightly above 1.0.

These plants have final scrubbers that are operated with sea water at a rate of 100 - 110 m³/hour for a production of 550-600 MTPD DAP. In 1984, when we started up the modified plants, we found that the sea water picked up 20 to 50 mg/l N, around 90 mg/l P₂O₅ (carry-over from the main scrubber) and about 1 mg/l F. At present, we are revamping these plants, with the objective, amongst others, to eliminate the need for sea water and to return the effluent from the (new) final scrubber into the process.

1.3. Selection of process equipment

The success of measures to reduce pollution depends to a large extent on the correct design and operation of the scrubbing system. Careful consideration is therefore necessary when selecting the type of scrubbers.

Of the various types of scrubbers Venturis with cyclonic separators are the ones most commonly used. They have a good efficiency for dust and gas absorption, have little tendency to plug and are easy to maintain. A significant disadvantage is the relatively high pressure loss.

Spray towers are empty towers with a large circulation distributed over the tower by means of spray nozzles. This type combines a low pressure loss with a low scrubbing efficiency. Formation of deposits poses no problems. The low scrubbing efficiency - about 0.8 to 1.2 NTUs per layer of spray nozzles - makes a careful selection of the scrubber arrangement necessary. UHDE prefers a variation of this type - the cyclonic spray tower - for reasons of energy conservation. We have achieved electricity consumption of only 30 kWh/ton for DAP, half of which was used for driving pumps and fans.

Packed towers are a third category - efficient but with increased pressure loss. Packed towers should be designed with high rates of circulation - at 50 to 75% of the upper limit of the loading zone. In plants for the production of NP/NPK fertilisers they are not commonly used as main scrubbers. This is due to the fear of deposits forming on the packing material. Packed towers have proved effective as tail-gas scrubbers downstream of primary scrubbers in granulation plants.

Deposits in scrubbers have two possible mechanisms: compounds present in the gas phase may be washed out and produce an insoluble substance by chemical reaction. An example is the formation of SiO_2 by hydrolysis of SiF_4 . The second mechanism is deposition of insoluble components from the scrubbing liquid itself as a result of reactions between the scrubber liquid and absorbed reactants. When phosphoric acid is used such reactions are common, as a result of ammonia absorption.

Crossflow scrubbers with proprietary packing material have performed well and have the advantage that the packing material can be cleaned easily [10].

2. Contain pollutants in a minimum of carrier (Step 3)

The basis for all considerations on the subject of pollution control is an accurate material- and heat balance. For a commodity like DAP these are widely known. Still there are a few issues to be discussed, which are valid for MAP/DAP as well as for NP/NPK fertilisers. The first issue is, that the plant heat balance can be effectively controlled by means of granulator ventilation. This is an efficient means of reducing the temperature in the granulation loop when the product formulation produces a large amount of heat in the granulator. This can be heat of reaction as well as heat of crystallisation. It applies for MAP and DAP as well as products such as 16-20-0 produced from ammonia, phosphoric and sulphuric acid. NP/NPK products with a high portion of ammonium nitrate react favourably on granulator ventilation. Granulator ventilation reduces the need for product drying. This means, for a new plant, a smaller dryer. For an existing plant the choice is between a lower product moisture and an increase in capacity. It also reduces the amount of air needed for drying. This is a second issue, concerning both pollution control and energy conservation. Total air consumption, including cooling and dedusting, should not exceed 3.5 to 4 kg per kg product. Even in existing plants this can be realised with a minimum of modifications.

A frequent consideration in plant modifications is the avoidance of liquid effluent. Ten years ago UHDE suggested a process scheme, that fully exploits the particularities of the system fluoride-phosphoric acid-ammonia-water [11]. We were led by data published by Hansen [12] on a plant start up in Aqaba. This plant has, due to the delicate nature of marine life in the Gulf of Aqaba, a closed scrubber system. The three conventional Venturi scrubbers operate with neutralised phosphoric acid at a M.R. of 1.2. It was reported, that this leads to very low fluoride losses and, even with a tail-gas scrubber that operates only with water, acceptable ammonia losses. With this information we undertook various experiments, early 1984, in a Turkish plant.

For the design of closed scrubber systems the equilibrium partial pressure of fluoride compounds over the circulating scrubber solution is of utmost importance. Based on Becker's graph [13] we developed an Antoine-type equation. At 55°C and with 0.1 to 5.0 gram/l F in the scrubber liquid the equilibrium partial pressure is about 5-6 mg/m³. The data of Pedersen [14] are slightly more optimistic in the temperature range that is of interest. German guidelines, which set the standards for most of continental Europe, allow, in case of recirculation of scrubbing solution, a maximum emission of 10 mg/m³ [15].

We can evaluate the above requirements, assuming two layers of spray nozzles with a total of two transfer units, using the equation:

$$NTU = \ln \frac{C_{in} - C^*}{C_{out} - C^*} \quad (1)$$

where

- NTU = the number of transfer units available in the scrubber,
- C_{in} = the concentration of fluoride in the incoming gas, mg/m³,
- C_{out} = the concentration of fluoride in the gas leaving the scrubber, mg/m³,
- C* = the equilibrium concentration of fluoride over the scrubber solution, mg/m³.

Using the figures mentioned above we find that the allowable inlet concentration of the fluorides to the final scrubber is 42 mg/m³. An example: if we consider a gas flow through the scrubber of 3 m³/kg of product and the water balance allows us to feed 70 litres of scrubber effluent per ton of product into the process, then the concentration of fluorides in the final scrubber effluent can reach about 1,600 mg/l.

PFI in Kavala, Greece operates an UHDE - built NPK granulation plant since 1982. The plant has a pipe scrubber downstream of the granulation drum, a main scrubber where the off-gas from the pipe scrubber and the drying drum are treated and a final scrubber. The pipe scrubber and the main scrubber have a common circulation system. It operates with dilute acid - 20 to 25% P₂O₅. The final scrubber is designed for seawater intake at a rate of 110 m³/hour. Actual circulation of sea water over the final scrubber is 420 m³/hour in two layers of spray nozzles. The scrubbers were designed and supplied by AIR INDUSTRIE, now called PROCEDAIR. They are of the GRANIVORE type, with a pressure loss measured from inlet to outlet of only 80 mm WC (800 Pa).

PFI's site lies on the shore of the Aegean sea. Around 1991 the company decided to change operation from once-through sea water to scrubbing with a dilute acidic ammonium sulphate solution. This solution can be returned to the process. The main reasons for this decision were the reduction of fluor load into the sea - the limit being 10 mg/l F - and the recovery of ammonia that was lost with the sea water. Modification of the scrubber system was a minor job that required only some piping and instrumentation. It was done by PFI's engineers. The modified scrubbing system has been running for about two years and the results have satisfied the owners. Emissions of F and ammonia are generally within the limits specified in the VDI-guidelines [15].

In 1993 contacts with another old client, Bandirma Gübre Fabrikalari A.S. (BAGFAS) in Turkey, led to a contract to modify and update two DAP/NPK granulation plants which UHDE had commissioned in 1979/80. One of the objectives is to eliminate the need for sea water in the final scrubbers (Figure 5). This plant uses pipe reactor technology and has a pipe scrubber downstream of the granulator with its own circulation. The main scrubber was modified in 1983, when one row of AIR INDUSTRIE spray nozzles was installed to improve efficiency. Turkish regulations allow a maximum discharge to the atmosphere of 30 mg/m³ of ammonia and 10 mg/m³ of fluorides. To achieve these values a new and more efficient final scrubber has to be installed. We selected a PROCEDAIR GRANIVORE scrubber with two layers of spray nozzles to do the job.

3. Recover airborne pollutants (Step 4)

Once the basis for the material- and heat balances has been fixed, the organisation of the recovery system has to be decided upon. From the heat balance we know how much water evaporation the scrubbers will be able to achieve. This should be the basis for decisions on how and where to recover dust. When the plant's water balance is tight, it may be wise to install bag filters but not, as has been recently suggested, downstream of fired drying drums [16]. UHDE has installed bag filters for dedusting off-gas from coolers and equipment dedusting. This air is relatively free from gaseous pollutants and need not be treated in a scrubber.

When a decision is taken to modify a plant, it should be considered how pollution control will be effected. The first and general rule for plant modification is : that as much of the existing equipment should be re-used as is reasonably justifiable. This means, that when Venturi-scrubbers are installed and in a decent shape, we have to live with it, despite their high energy consumption, unless we are instructed differently. In a recent revamp in an American-built NPK plant in South Africa the primary objective was to increase output and improve product quality by installing a pipe reactor in addition to the preneutraliser. Material- and heat balances showed that the granulation drum had to be ventilated beyond the capacity that could be ensured by the air flow over the R/G scrubber.

We decided to replace the R/G Venturi by a pipe scrubber with a separate circulation system. The system operates with concentrated phosphoric acid as the scrubbing medium. From there the pipe reactor and the pre-neutraliser are supplied. The low pressure loss made it possible to combine the off-gas from the new R/G pipe scrubber with the off-gas going to the C/E Venturi (Figure 6). To this end we reduced the airflow over the process cooler and increased the pressure loss over the process cooler cyclones. In this way the off-gases from pre-neutraliser, pipe reactor and granulator are treated a second time. The lower operating temperature in the C/E Venturi guarantees an efficient second stage scrubbing. The system works well for products with a high M.R. For products on basis of MAP we experienced, however, a considerable fume off of fluorides that originated from the pipe scrubber. The M.R. in the pipe scrubber circuit for such formulations remains under 0.2. This is exactly the situation reported by Boontje et al. [3], who had already given the solution. We recommended our client to split up the phosphoric acid to control the M.R. in this circuit in the range of 0.3 to 0.6. This brings the flexibility to operate over the whole range of product mole ratios.

4. Nitrogen oxides from compound fertilizer production

Formation of nitrogen oxides, NO₂, NO and N₂O, is experienced mostly in plants with a nitric or mixed acid attack section. Beyond the dissolving stage they can be observed only in neutralisers, granulators and drying drums under excessive conditions.

The amount of NO_x emitted in a nitric acid attack depends to a large extent on the temperature. Even more important, however, is the content of organic matter in the rock. We have found that at reactor temperatures of 70 to 75°C about 35 to 50% of organic matter is oxidised by nitric acid. This leads to the emission of nitrous oxides formed according to the following overall reaction:



Igneous and calcined rocks that contain low amounts of organic matter only emit low amounts of NO_x during digestion [17].

When acid from a mixed attack section is neutralised in a pipe reactor at a pressure of 300 to 500 kPa and a temperature of 155 to 165°C, NO and NO₂ will be formed. Likewise, when a fertiliser containing ammonium nitrate is "backtitrated" in the granulator with sulphuric or phosphoric acid, ammonium nitrate may decompose and form nitrogen oxides. Hansen [18], reports formation of N₂O in granulator fires without mentioning the cause for it. In the production of ammonium nitrate by neutralising nitric acid with ammonia at elevated pressure and temperature the designer should be aware of the fact that, due to the stainless steel used in the reactor, measurable amounts of dinitrogen oxide, N₂O, can be formed [19]. Other reasons for formation of nitrogen oxides in the granulation system are a too low pH of the product and too high air temperature in the drying drum.

The most common source of emission of nitrogen oxides remains attack of phosphate rock by nitric acid. When we consider the case of two competing reactions in one or more CSTRs, one fast and desirable the other slower and undesirable, and study the effect of temperature and residence time requirements to complete the desired reaction to a defined degree, we will find the conditions for maximum suppression of the undesired reaction:

- a. a temperature to be selected as low as practicable and
- b. a maximum number of reactors in series.

Since we have to find an economical solution, a compromise has to be made. Such a compromise, depending on the reactivity of the rock and the amount of unconverted material that we tolerate, could be: a temperature of 65 to 70°C, two or three reactors and a residence time between 45-90 minutes.

Several other measures can be taken to reduce formation of nitrogen oxides. The most effective one is to select a phosphate rock with a low content of organic material. This may be an igneous rock - Kola has been, straight or mixed with a sedimentary rock, a favourite of nitrophosphate producers - or a calcined rock. Although the addition of urea does not really suppress the formation of nitrogen oxides - it merely destroys them to form nitrogen before they can escape from the reactor solution [17] - it should be mentioned here. The economics are not very good. For a rock that forms 12 kg of N as nitrous oxides per ton of P₂O₅ in rock, and dosing of urea at 50 % over stoichiometric, this measure requires 40 kg urea per ton of P₂O₅ from rock. Neither the use of a rock low in organic material nor the addition of urea to the dissolving reactor will reduce emissions to below the highest level considered acceptable by the current VDI guidelines: 1,000 mg/m³ (expressed as NO₂) for once-through scrubbing with water.

This brings us to the subject of scrubbing nitrogen oxides. The compounds to be removed are normally NO and NO₂ in approximately equimolar quantities. These form, with water, nitrous acid which is particularly unstable in an acidic environment. Acidity is always present in the form of nitric acid which is co-absorbed or formed from nitrous acid under desorption of NO. Under conditions prevailing in effluent from once-through scrubbers with water as the absorbing solution nitrous acid will rapidly decompose into nitrous oxides and water. This means, that when nothing is done to fix the nitrous acid chemically, the nitrogen oxides are merely redistributed. Catalytic destruction and recovery of nitrites by alkaline scrubbing are complicated by the presence of fluorides - mostly as SiF₄ - in the raw off-gas.

In 1986 UHDE and BASF were confronted with this dilemma when we designed and engineered a nitrophosphate plant for AGROLINZ, Austria. One of the objectives of the project was to reduce the environmental burden of fertiliser production at an existing site, whilst maintaining production capacity [20, 21]. A semi-quantitative balance of environmental aspects of a typical nitrophosphate plant is given by Reuvers [22]. At first instance it was decided to design a conventional scrubbing system operating with once-through water. To reduce the nitrite load to below the contractual limit of 3.5 kg/h nitrite-N a series of three reactors was installed. The reactors use a urea-solution to react with and eliminate the major portion of the nitrous acid before disposal.

Simultaneously with the engineering work of this scheme UHDE and BASF worked out a process-scheme that would eliminate waste water from the nitrite decomposition reactors completely. A dilute ammonium nitrate solution was used as the absorbent. By controlling the pH of the solution after scrubbing nitrous acid was fixed as ammonium nitrite.

To regenerate the absorbing solution the ammonium nitrite has to be removed. This can be done by reaction of the nitrite with urea or by thermal decomposition. Tests were undertaken in Ludwigshafen. Shortly after start-up AGROLINZ decided to have the once-through system redesigned to allow recirculation. Actually, during the design stages this had been taken into account, which made conversion easy. The circulation system (Figure 7) has been operating since late 1991 and, regarding the destruction of nitrites, has behaved better than expected. The version with thermal decomposition, which does not consume any additional chemicals [23], is clearly the better choice. Some difficulties arose from the deposition of silicates in the system, preferably on heat exchanger surfaces. Although the level of nitrous oxides in off-gas is lower when urea is added, the version with thermal decomposition remains well below the limit of 500 mg/m³ (expressed as NO₂) valid for alkaline scrubbing systems set in the VDI guidelines [15]. Since the system is of the add-on type, it is well suited for plant modifications.

CONCLUSION

Fertiliser plants can be modified for a variety of reasons. Such reasons are usually of an economical nature. In many countries emission control has become an economic issue. In such cases it is automatically included in the objectives to be studied. Even when emission control is not an economic issue, the economic aspects of it should be carefully considered. Many of the measures to reduce emissions are low cost items, requiring more knowledge and common sense than capital. Other measures can contribute, through the proper selection of emission control equipment, its organisation and operating conditions, to lower energy cost per unit product or to increased output. The primary rule for any plant modification is that as much of the existing equipment should be re-used as is possible.

In our review we have included the most common pollutants which we encounter in the fertiliser industry: ammonia, fluoride, nitrogen oxides and fertiliser dust. We have considered the case of the closed scrubber system, which should become the industry's standard. In decisions on pollution control the energy costs associated with it should be given a higher priority.

In planning a plant modification a systematic approach with respect to environmental issues (emissions and energy conservation) should be undertaken. For this we have developed and demonstrated a 4 - step procedure. Starting at the source the scope of the plant investigation is widened until the battery limit is reached.

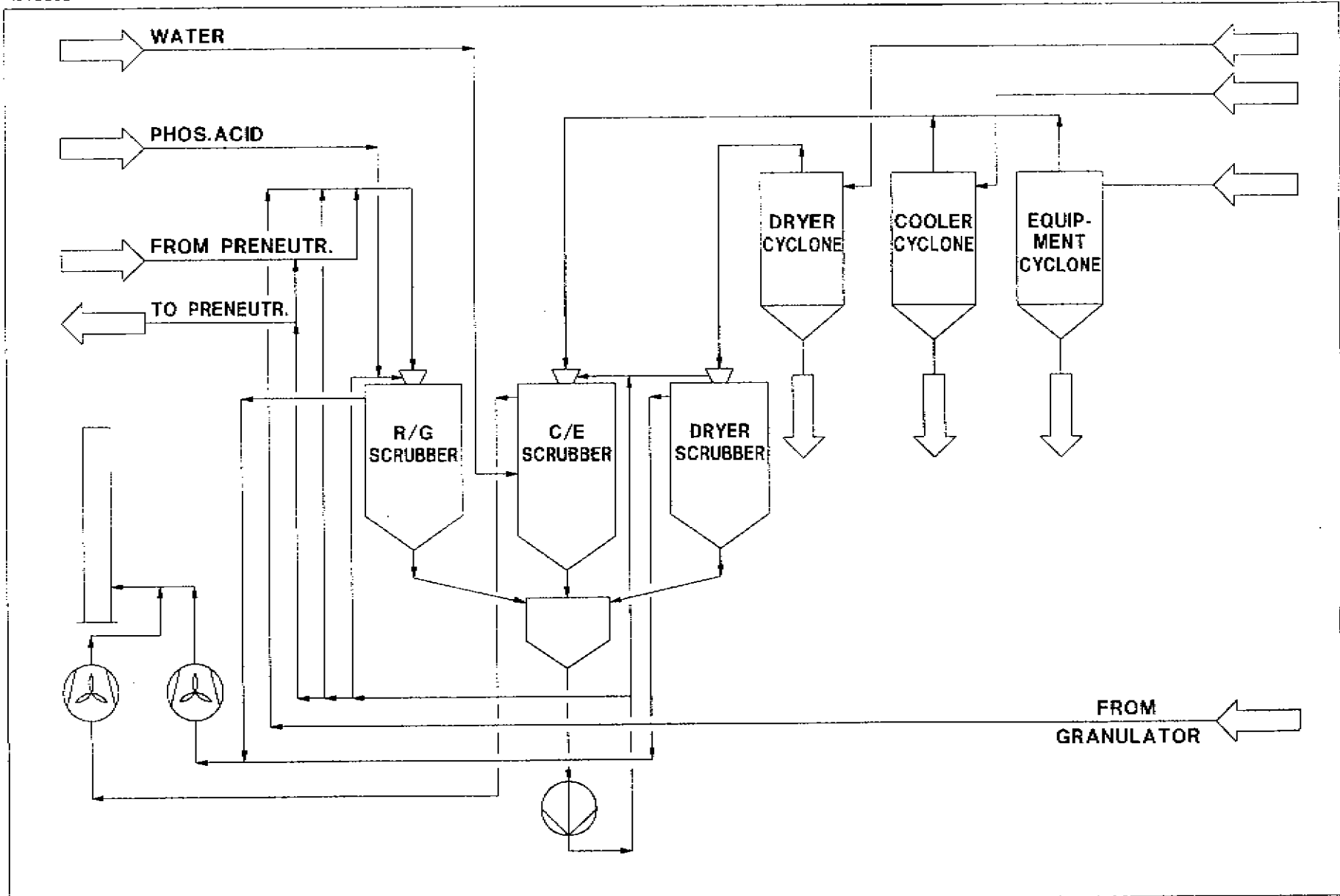
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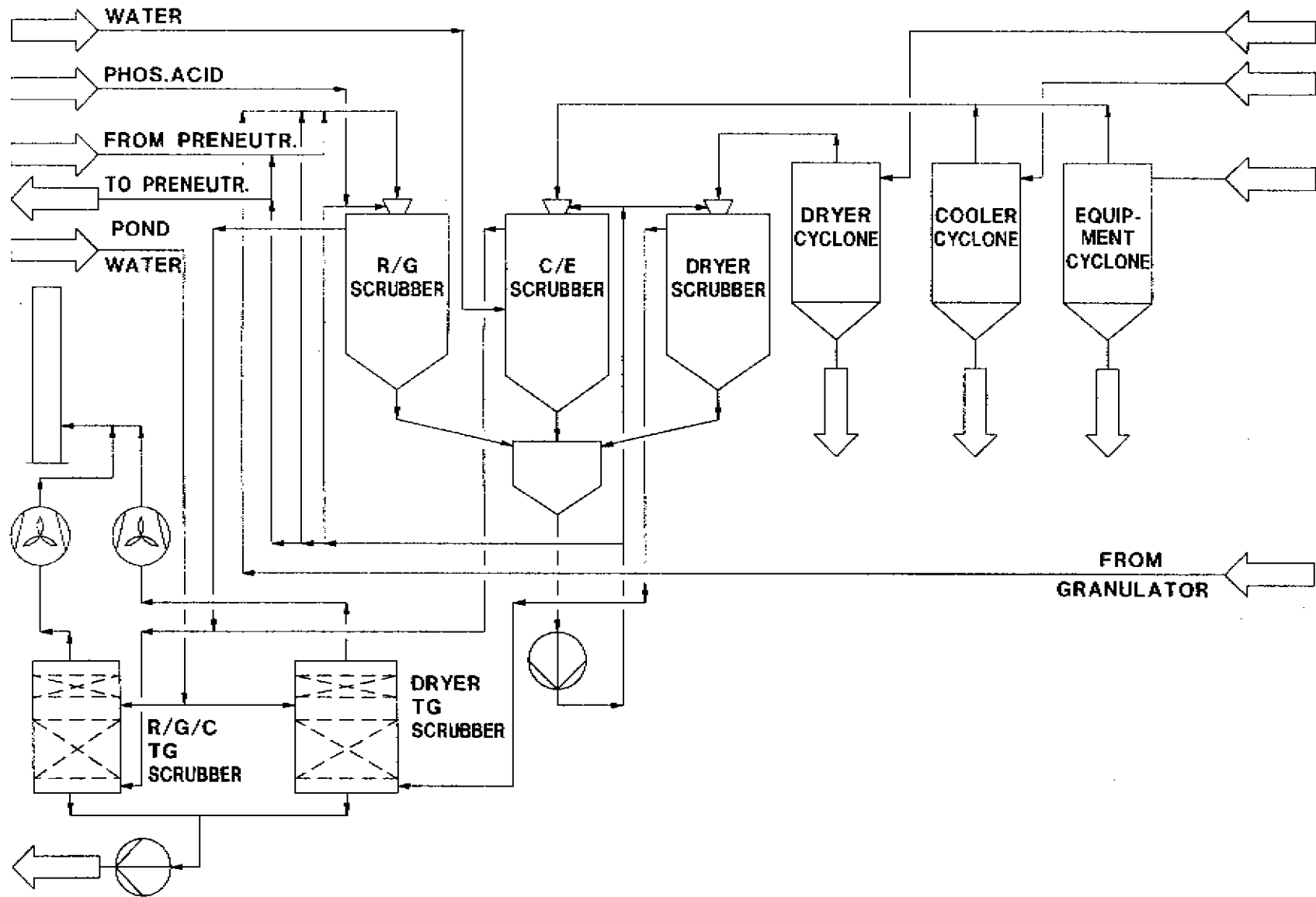
As an engineering company, we do not have the facilities to test and investigate the problems occurring in fertiliser plants. We are therefore dependent on the willingness of our clients to undertake the necessary experiments, which sometimes entails major process disruptions. For their help in the development of new process options, we would like to thank all our clients, particularly Mr. N. Simoglou of PFI, Greece and Mr. J. Grausam of AGROLINZ, Austria.

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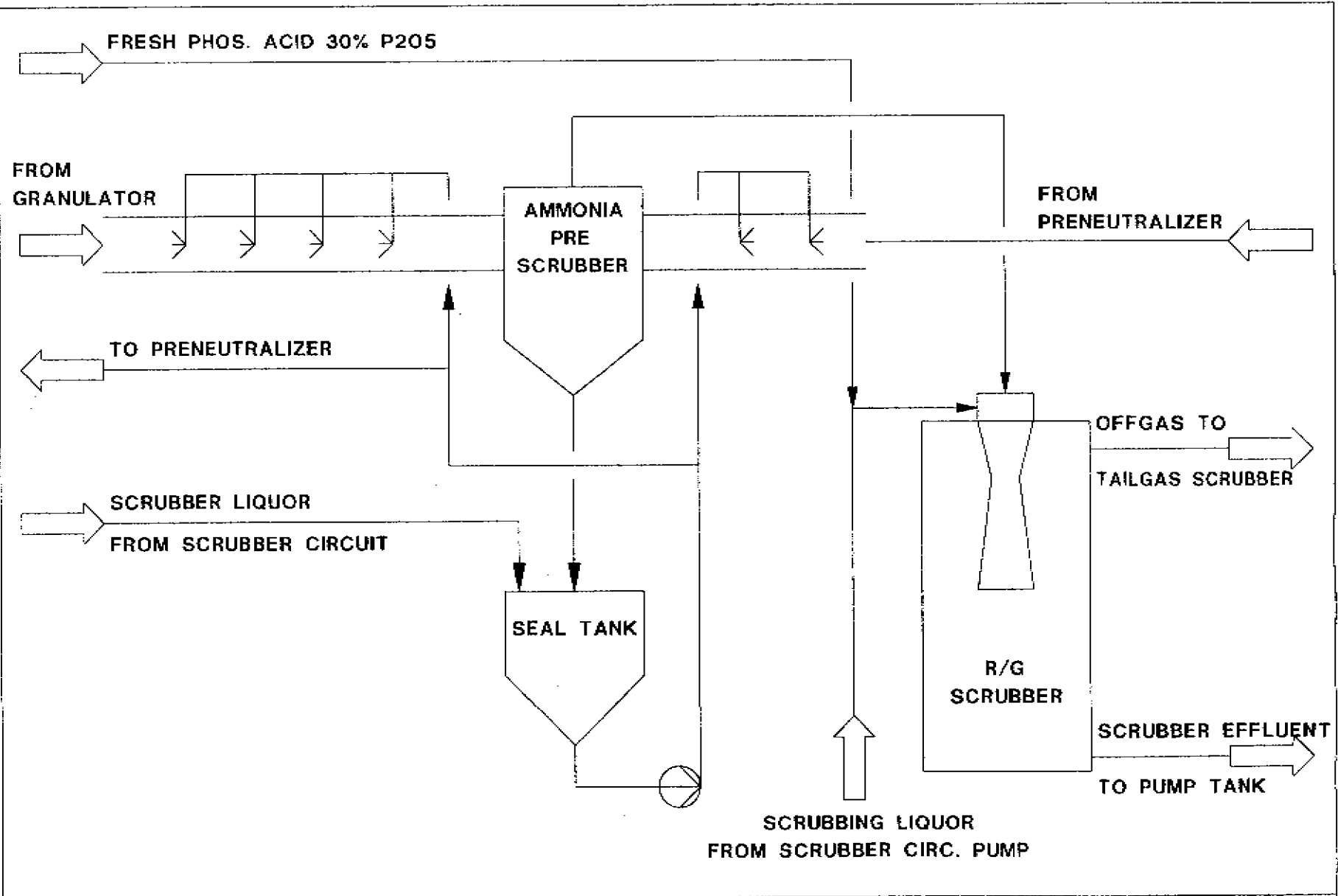
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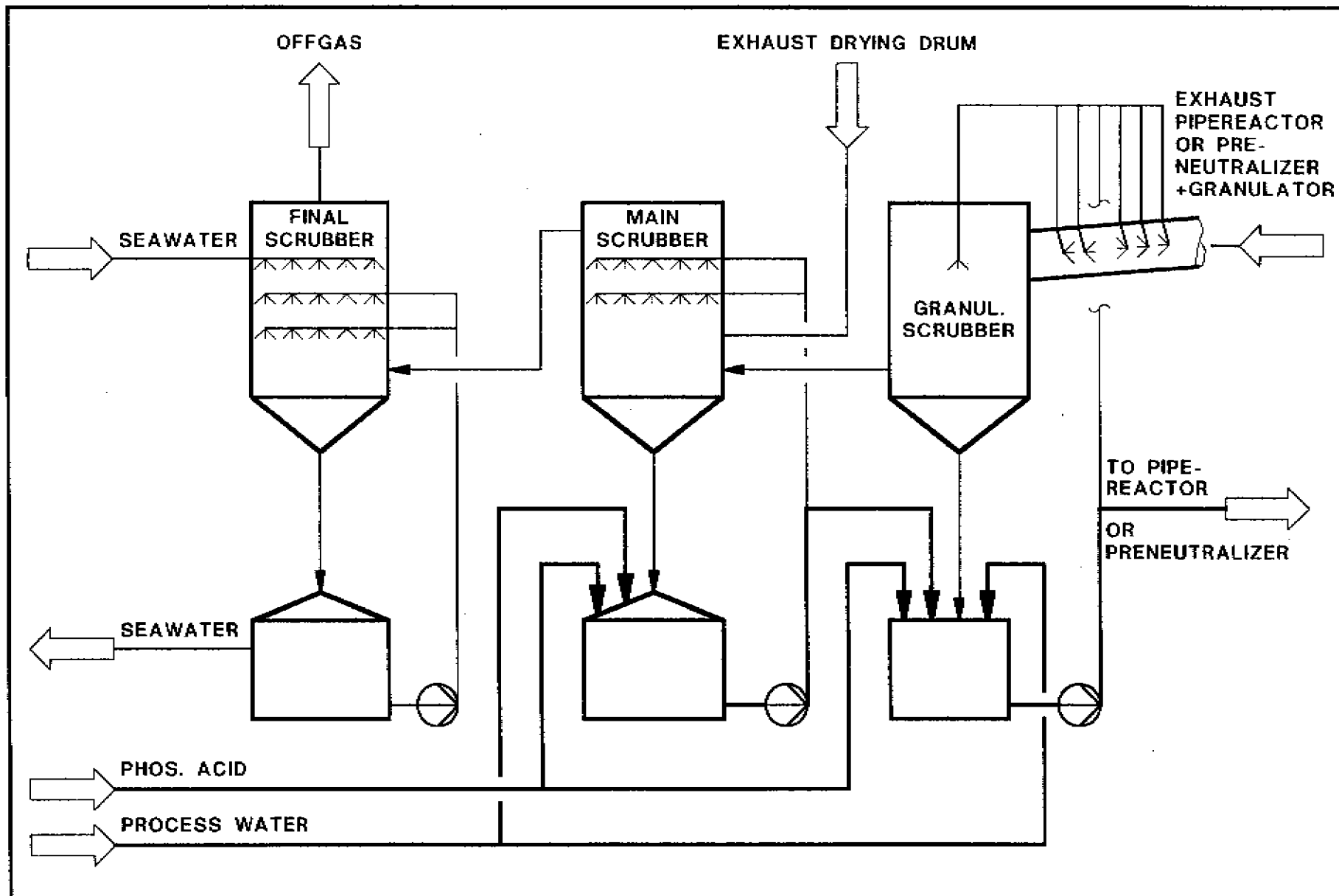


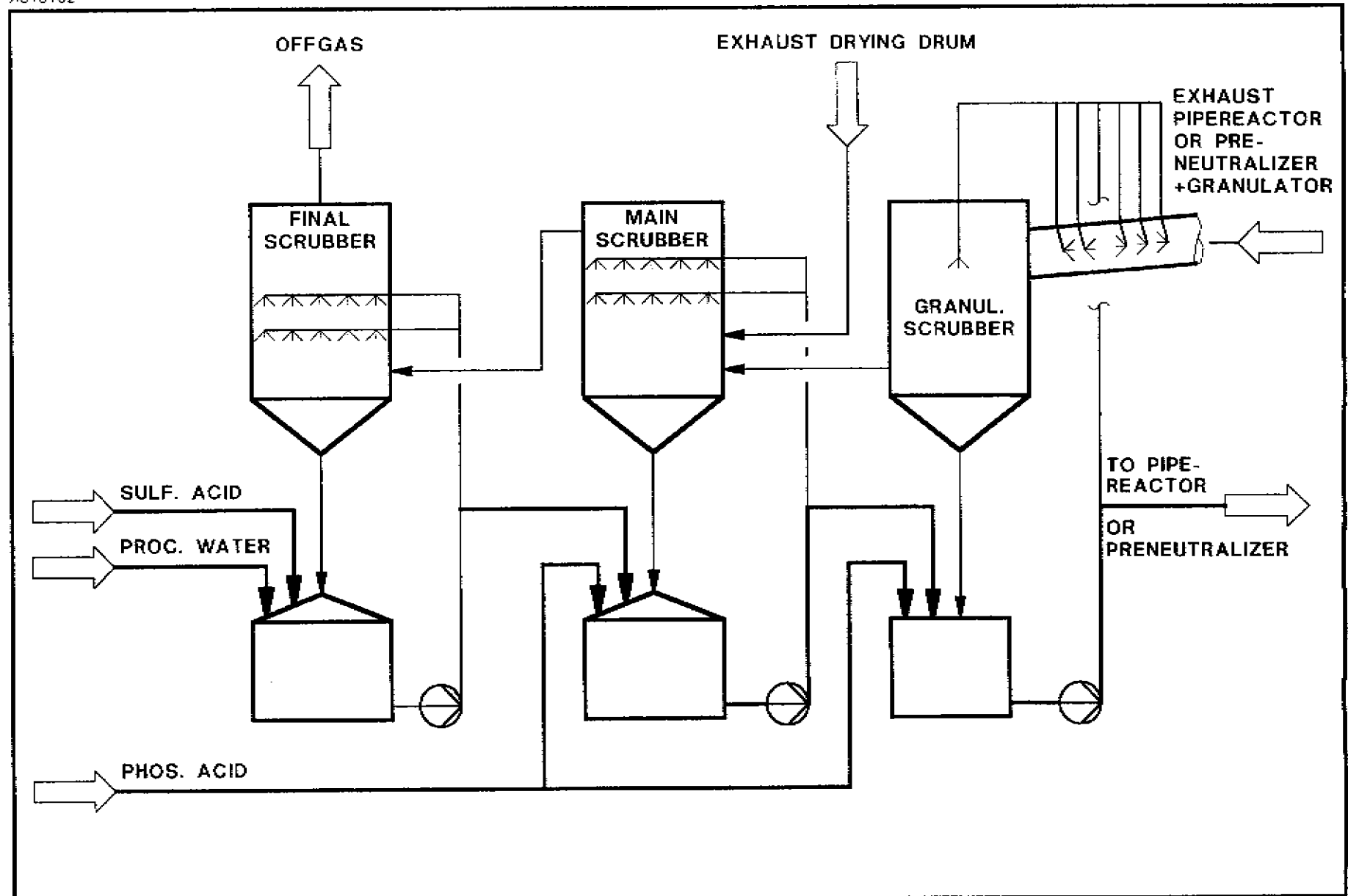
THREE VENTURI SCRUBBER ARRANGEMENT IN COMBINATION WITH TWO TAILGAS SCRUBBERS

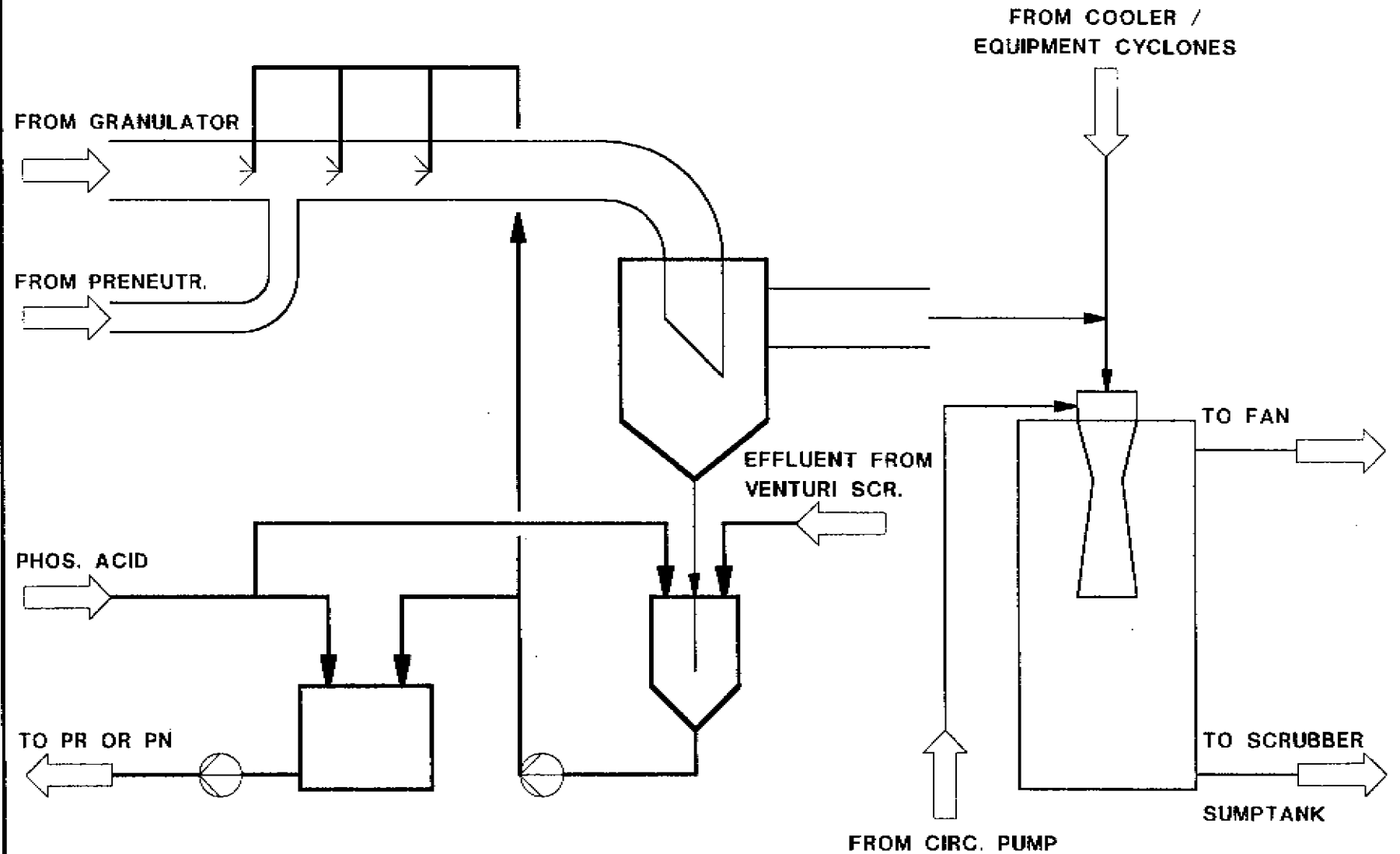
FIGURE 2



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UHDE VERSION OF DOUBLE MOLE SCRUBBING SYSTEM WITH SPLIT PHOS. ACID FLOW

FIGURE 6

