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**Meeting environmental issues facing new
and existing urea Fluid –bed Granulation with Plants**

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Meeting environmental issues facing new and existing urea fluid-bed granulation plants

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Abstract : In recent years many environmental regulations have been amended by the regulatory bodies. This has led to a significant reductions in the permissible emission levels for ammonia and urea dust for new urea fluid-bed granulation plants. Existing plant operators are also faced with the demands from their environmental authorities to reduce their emissions to the environment as well.

While the reduction of dust emissions can be achieved by using scrubbing systems with a higher separation efficiency, reducing ammonia emissions in a urea granulation plant is more complicated. In principle significant ammonia reductions can be achieved by installing acidic scrubbing systems well known in the fertilizer industry.

In NPK or AN plants the resulting bleed stream from the acidic scrubber can be reintroduced into the process without any difficulty, as in these plants the bleed contains components which are already present in the plant and the product. For a urea fluid-bed granulation plant the situation is more complicated. In this case the bleed from the acidic scrubber contains components which cannot be processed in a standard urea synthesis and evaporation plant and which until now are usually not part of the product specification.

The bleed from the ammonia scrubber must be processed in some way. This processing can be done in various ways.

In accordance with UFT's commitment to improve the fluid-bed granulation process UFT has developed options for achieving ammonia emission reductions from fluid-bed urea granulation plants.

With UFT's Ammonia Convert Technology the acidic bleed from the ammonia scrubber has been successfully integrated into the granulation process.

In this paper various available and industrially proven options for granulation plant operators are presented. In especially UFT's proprietary Ammonia Convert Technology, which combines minimized ammonia emissions with reduced production cost will be discussed.

1 The UFT Fluid Bed Urea Granulation Technology

Figure 1 shows the process flow diagram of the UFT Fluid Bed Urea Granulation process. Heart of the plant is the granulator, where urea solution with a concentration of 97% is atomized into fine droplets and sprayed onto the particles in the fluidized bed. Formaldehyde is added to the urea solution as granulation additive and to improve storage properties.

Crushed oversize and fines coming from the screens are utilized in the granulator as seed material and the particles continuously grow to their desired size by accretion. In the first cooler the product is cooled down and via bucket elevator lifted to the screens, which separate coarse, fine and on-size material. The on-size material is cooled down in the final cooler to the storage temperature and sent to storage.

The major advantage of the UFT fluid bed urea granulation process is the melt concentration of 97% urea. In this way the evaporating water is utilized in the granulator as additional coolant to remove the heat of crystallization. This leads to the following features:

- Single stage evaporation unit in urea synthesis section
- Low biuret concentration in final product
- Low quantities of fluidization air needed in granulator
- Lower investment cost due to smaller granulator, less fluidization air, smaller scrubbing unit and single stage evaporation unit
- Low steam consumption in evaporation and granulation
- Low electrical energy consumption due to low amount of air required

Figure 2 shows a typical plant concept for a world class granulation plant. In this concept it can easily be seen that the treatment of the off-gas from the granulation unit is a large section of the granulation plant. The scrubbing systems for the air from the granulator and the fluid bed coolers therefore contribute significantly to the investment and operating costs of the plant.

Their careful design and good operation are just as important as that of the granulation loop.

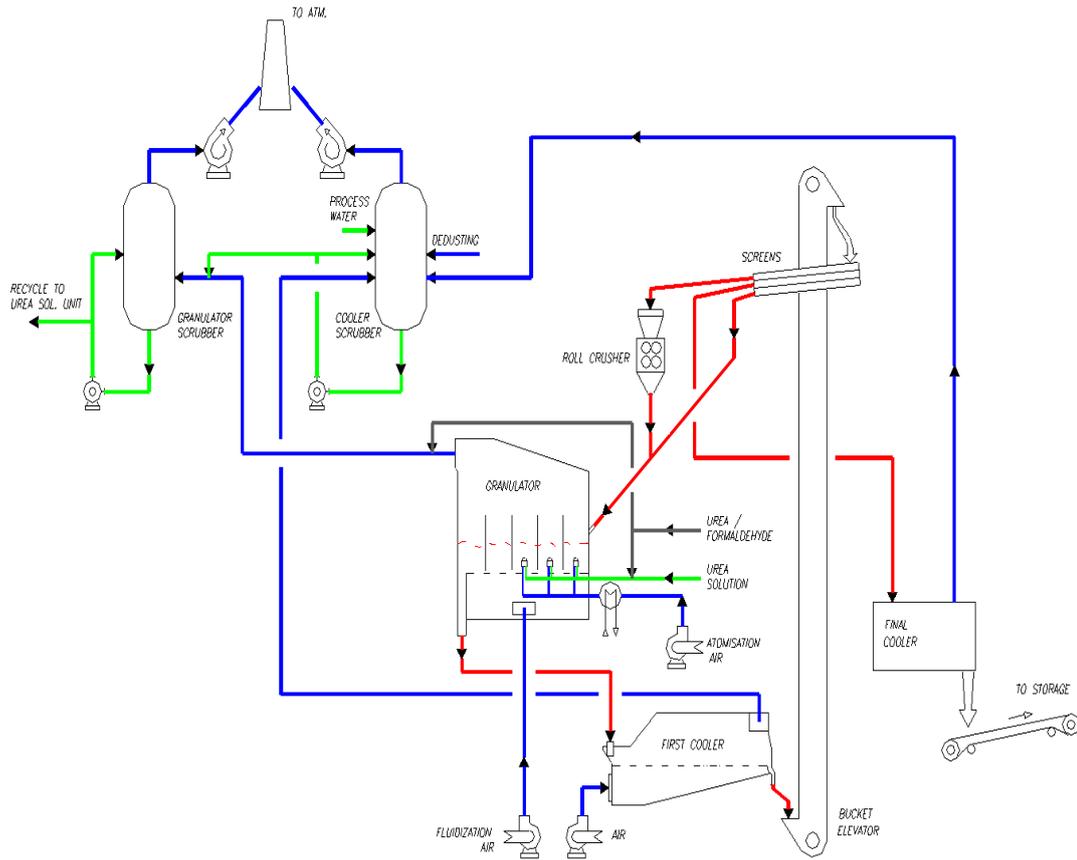


Figure 1 - Schematic of UFT granulation process

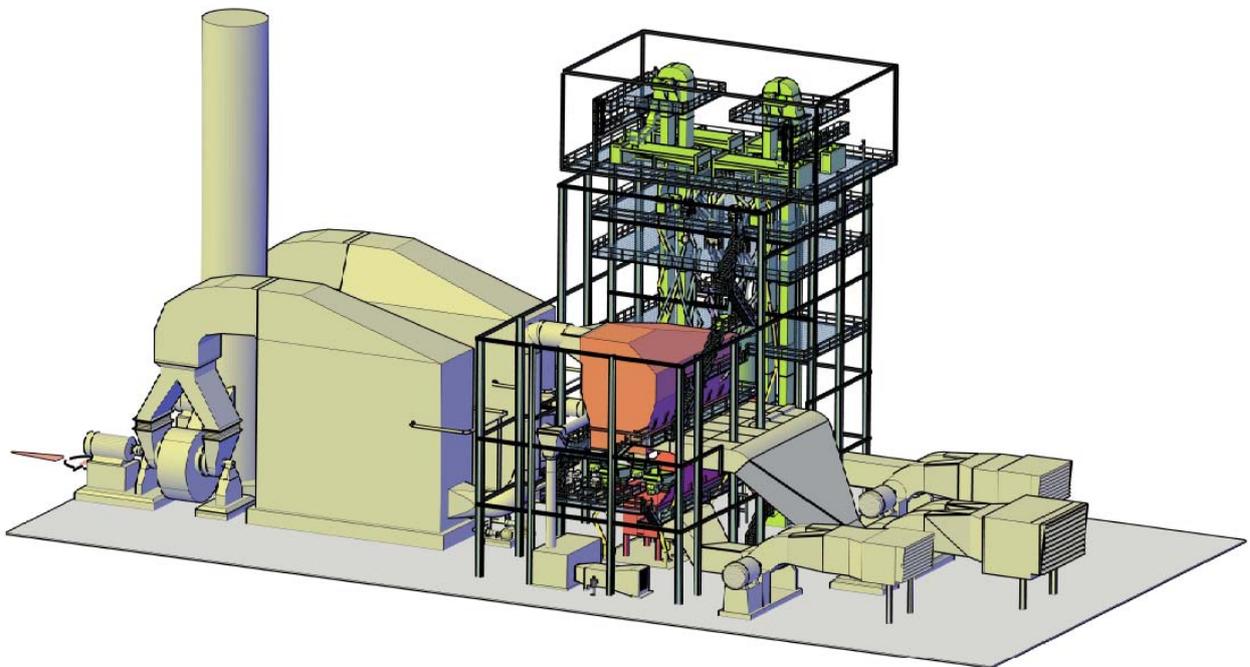


Figure 2 - World Scale Fluidized Bed Urea Granulation Plant

2 Emissions and emission limits from a fluidized bed granulation plant

There are three sources of emissions from a fluidized bed urea granulation plant

- dust or particulate matter
- ammonia
- water vapor (opacity)

Since the last decades emission limits have been a key focus of the environmental protection agencies. With the development of technology and increased public awareness the emission limits required by the regulatory authorities or recommended by leading institutions have been continually reduced. While the reduction of the permissible values primarily focuses on new plants and can be taken into account during the design.

However, with plant lifetimes of over 30 years, some older plants are now also required to achieve lower emission figures than was foreseen during their original design. Alternatively the new emission limits are imposed when the plant is debottlenecked. This poses additional challenges as the limitations of the existing facilities and the available space must be taken into account.

Source	Dust	NH ₃
PPAH (World Bank, 1998)	< 50 mg/Nm ³	< 50 mg/Nm ³
EFMA BAT Booklet (2001)	< 50 mg/Nm ³ < 0.25 kg/to	< 50 mg/Nm ³ < 0.25 kg/t
EU BREF LVIC (2007)	< 15 – 55 mg/Nm ³	< 3 – 35 mg/Nm ³
Saudi Arabia (RCER 2010)	< 0.25 kg/ t	< 50 mg/Nm ³
UAE (2011)	< 30 mg/Nm ³	< 30 mg/Nm ³
Malaysia (2011)	< 30 mg/Nm ³	< 76 mg/Nm ³

Table 1 : Development of the emission limits since 1998

While the World Bank or the International Financial Corporation (IFC) do not directly proscribe emission limits, their recommendations form the basis for the international financing organizations. These assess the financing of projects according to the so called "Equator Principles". This is a financial industry benchmark for determining, assessing and managing social and environmental risk in project financing which is based on the Pollution Prevention and Abatement Handbook (PPAH) of the World Bank.

Currently the PPAH is being revised by the World Bank. From the drafts which have been published it is expected that the recommendations from the European Union BAT Reference document for Large Volume Inorganic Chemistry plants (BREF LVIC) will be the basis for the revised PPAH.

With increasing plant capacities the amount of emitted material from a single source has risen considerably. It is therefore worthwhile to invest in emission reduction systems which return the emitted material back to the process. However, particularly for ammonia emissions, only a few producers have taken up the challenge to reduce the emissions drastically. Available emission reduction technologies often being considered as unattractive or deemed only possible for plants serving a 'closed' market.

3 Dust emissions

The fluidized bed urea granulation plant is a solid-handling process. This means that solid material is transported and handled. In addition a melt is atomized into fine droplets and injected into the fluidized bed. All these actions can lead to dust formation and agglomeration. This is common to all granulation processes and entails that the plant must be cleaned at regular intervals.

Sources of dust :

- granulator (80 - 90%) – mostly coarse dust but also some fine dust which is difficult to remove
- coolers (10 - 20%) – mostly coarse dust, easy to remove
- material handling, in particular from the crushers – only traces

3.1 Dust emissions control

As shown above the operational possibilities to reduce dust emission are limited. Therefore dust scrubbing systems are standard for fluidized bed urea granulation plants. This is not only due to environmental reasons but also as a significant amount of product, which would otherwise be lost, is recovered and reintroduced into the process. A typical example for a dust scrubbing system is shown in Figure 3

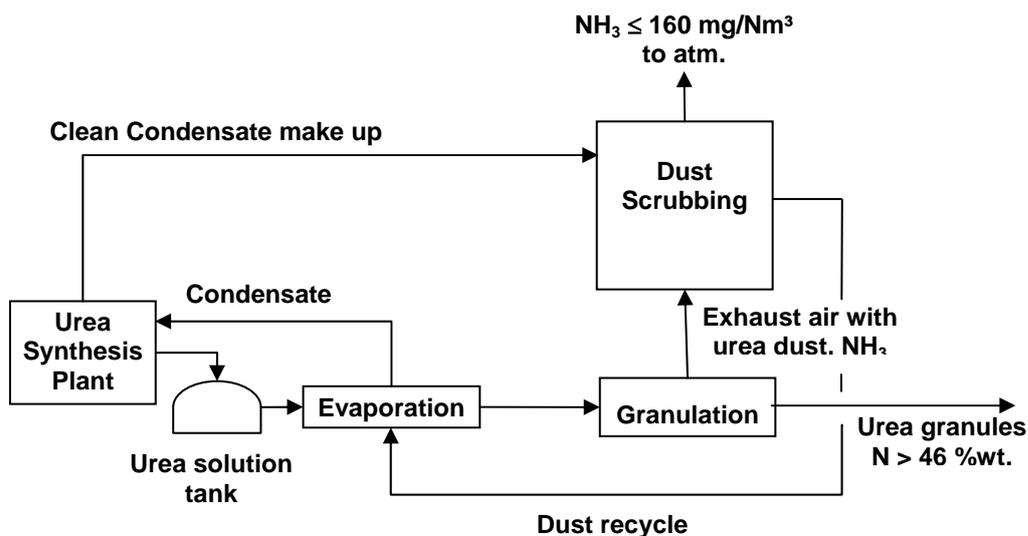


Figure 3 : Conventional Urea Dust Scrubbing system

As urea is very hygroscopic wet scrubbing systems are preferred. These systems can utilize the following types of scrubbers :

Vertical scrubbers :

- Venturi type scrubbers
- Tray type types
- Packed bed types, usually with random packing

Horizontal scrubbers

- random packing
- structured packing

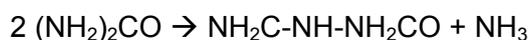
As the dust scrubbing systems are purely water based the reduction in ammonia emissions in such a system is minimal.

4 Ammonia Emissions

The ammonia emitted from the urea granulation plant is to a large extent not generated in the granulation plant, but enters the granulation plant with the urea solution. The amount of ammonia contained in the urea solution is the result of the conditions in the evaporation section. The ammonia is released from the urea solution during the spray of the urea solution into the fluidized bed.

If we assume a typical ammonia concentration in the urea solution of 600 ppm wt the ammonia concentration in the off gas is about 130 - 160 mg/Nm³, corresponding to a specific emission of 0.6 -0.7 kg ammonia per ton urea.

A much smaller amount of NH₃ is formed during the formation of biuret in the melt line between urea solution feed pump and the granulator spray nozzles. During the polymerization of urea to biuret ammonia is released, as shown in the reaction below.



Free ammonia from evaporation section	≈ 500 to 600 ppm wt
Ammonia from biuret formation	≈ 90 ppm wt
Total free ammonia at granulator inlet	590 to 690 ppm wt
Free ammonia in final product	≈ 50 ppm wt
Free ammonia released (based on urea solution)	≈ 540 to 640 ppm wt

Table 2 : Sources for ammonia emissions in a fluidized bed urea granulation plant

4.1 Process possibilities to reduce Ammonia emissions

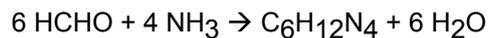
- (1) The atomization and fluidization air to the granulator effectively 'strip' the NH₃ contained in the concentrated urea solution, the NH₃ content in the urea solution should therefore be as low as possible. This can only be done by the adjusting the operating conditions in the urea synthesis and evaporation units.
- (2) The polymerization of urea to biuret releases ammonia, therefore the biuret formation between evaporation and granulation units must be minimized.
 - Do not overheat the urea solution to the granulator e.g. high steam pressure on tracing or jacketing
 - Reduce residence time of urea solution at elevated temperatures (> 120°C)
 - Residence time and biuret content Increase when the capacity of the granulation plant is reduced
 - Do not recycle urea solution unnecessarily.
- (3) The process water from the melt plant often contains NH₃. This water as make-up water for the scrubbing system of the granulation plant. Any NH₃ in the process water will be stripped in the dust scrubbers and increase the NH₃ emissions.

5 Ammonia Emission control

With a purely water based scrubbing system the gaseous ammonia released cannot be removed effectively. The reason is the low solubility of ammonia in water under the prevailing temperature in the atmospheric scrubber (~ 45°C). As the operational options for the reduction of ammonia emissions are limited, additional ammonia reduction systems are required to meet the new environmental legislation.

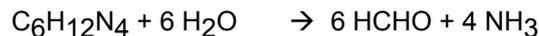
5.1 Ammonia Abatement System

The ammonia abatement system is based on the reversible gas phase reaction of ammonia with formaldehyde. The formaldehyde is injected into the exhaust air duct from the granulator to the granulator scrubber and in the finely dispersed droplets formaldehyde reacts with the gaseous ammonia to form hexamethylenetetramine.



Formaldehyde + Ammonia → Hexamethylenetetramine + Water

The hexamethylenetetramine is returned with the urea solution recycle to the evaporation section in the melt plant. Under the prevailing conditions of pressure and temperature in the evaporation unit the hexamethylenetetramine complex decomposes into formaldehyde and ammonia. The ammonia leaves the evaporation section with the vapors and is recovered in the urea synthesis, while the formaldehyde is absorbed in the urea solution and sent to the granulator.



Hexamethylenetetramine + Water → Formaldehyde + Ammonia

In total formaldehyde balance no additional formaldehyde is required to operate the ammonia abatement system. This system was developed and patented by Hydro Agri, the predecessor company of UFT. A number of ammonia abatement systems are in operation. A more detailed description can be found in the literature.

The ammonia abatement system, such as shown in Figure 4, will only reduce the amount of ammonia in the off-gas by approximately 25 – 40%. Unfortunately this is often not sufficient to achieve modern emission levels.

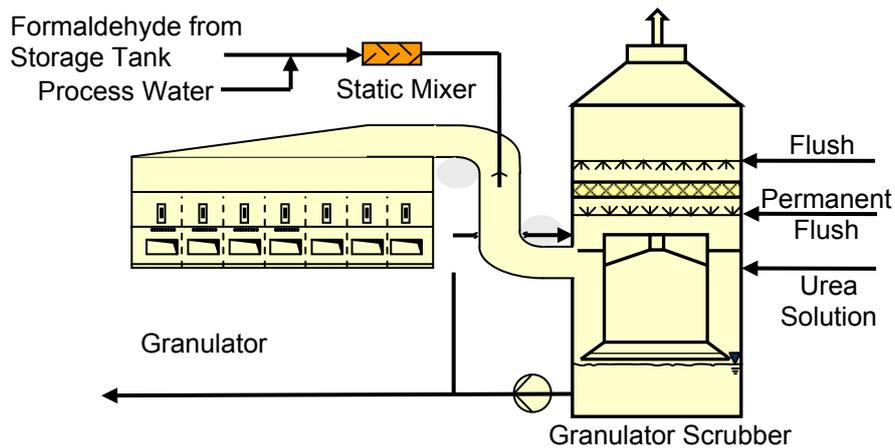


Figure 4 Typical Ammonia Abatement System

As can be seen in figure 4 the ammonia abatement system only requires the installation of a small amount of additional equipment - an additional UF line with a static mixer and a spraying system in the duct between granulator and dust scrubber. The total amount of formaldehyde does not increase ! The formaldehyde required according to the product specification is split between the feed to the urea solution and the scrubber.

5.2 Acidic Scrubbing

While such systems are long established in other fertilizer plants e.g. AN/CAN or DAP/NPK, for urea plants these systems produce a fundamental problem. The bleed streams from the ammonia reduction systems introduce foreign components which cannot easily be processed in the NH_3 / Urea complex. These 'new' components, mainly ammonia salts, would cause serious corrosion and other problems for the urea synthesis unit.

With an acidic scrubbing system as shown in Figure 5 the ammonia emissions from a UFT granulation plant can be reduced to less than 0.2 kg/ton of product, corresponding to about 30 mg/Nm³.

Many different acids could be used, in practice only two mineral acids are used. The most common systems use sulfuric acid. This is readily available and the resulting salt solution – ammonium sulfate – is easily handled. The sulfuric acid is added to the dilute circulating ammonium sulfate solution. The slightly acidic and dilute ammonium sulfate solution then fed to an separate acidic scrubbing stage installed downstream the dust scrubbing section. In the acidic scrubbing stage the gaseous ammonia the ammonia reacts with the acid to form ammonium sulfate. The resulting ammonium sulfate solution must be drained off continuously to keep the salt concentration in the acidic scrubbing loop constant.

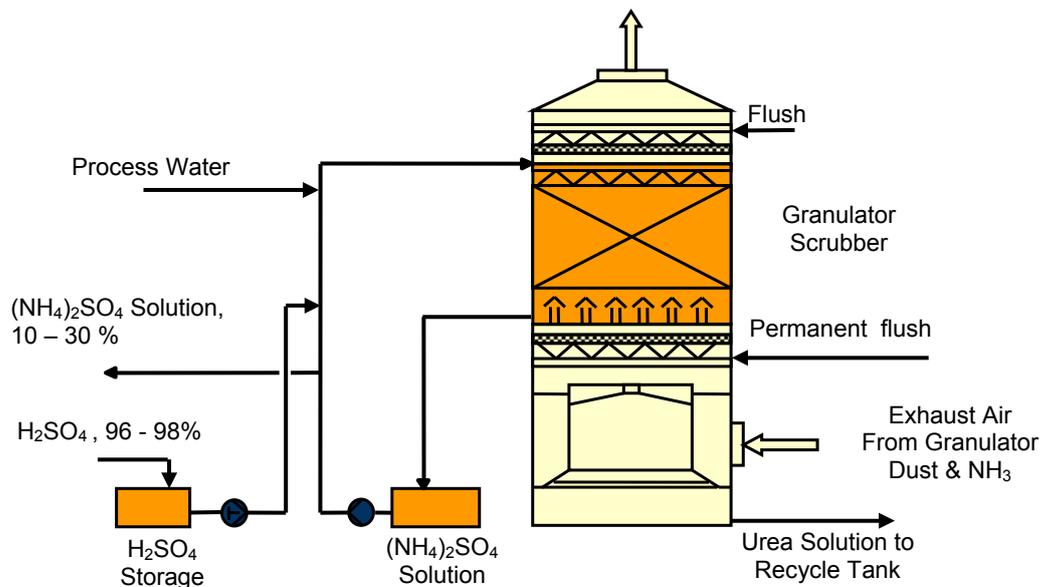


Figure 5 - Typical Acidic Scrubbing System

An alternative to sulfuric acid is nitric acid. The efficiency and the process is the same, but there is a safety issue. Apart from dealing with dilute ammonium nitrate solution there is the danger that at low pH the nitric acid and urea react to form urea nitrate. Urea nitrate is highly explosive. Therefore special attention must be given to control the pH of the acidic scrubbing section. In addition great care must be taken to prevent dead – spots in the equipment and piping where nitrate containing material could crystallize and accumulate.

Basically the same safety requirements as are required for the handling of dilute ammonium nitrate solutions must be implemented. These require special pump designs, additional instrumentation and washing facilities that ensure that all traces of nitrate containing material are flushed from the scrubbing system thereby preventing any accumulation of nitrate material, e.g. in areas of the scrubber system which are not wetted continuously.

Ammonium sulfate can be used as a liquid fertilizer, as a feed stock in a NPK plant or crystallized. The nitric acid option is usually only feasible for sites which have a nitric acid / ammonium nitrate facilities. In this case the ammonium nitrate solution can be sent to the ammonium nitrate plant, e.g. for producing UAN solution.

While conventional acidic scrubbing (Figure 6) systems are very efficient and well proven, they require a number of additional measures:

- precise separation of the dust and ammonia removal sections.
This requires separate scrubber stages and separate scrubber circulations systems
- they produce a salt solution which is not easily integrated into the existing facility.
As the salt solution cannot be disposed to a waste water treatment facility, it requires additional units , e.g. a crystallization unit or a UAN plant.

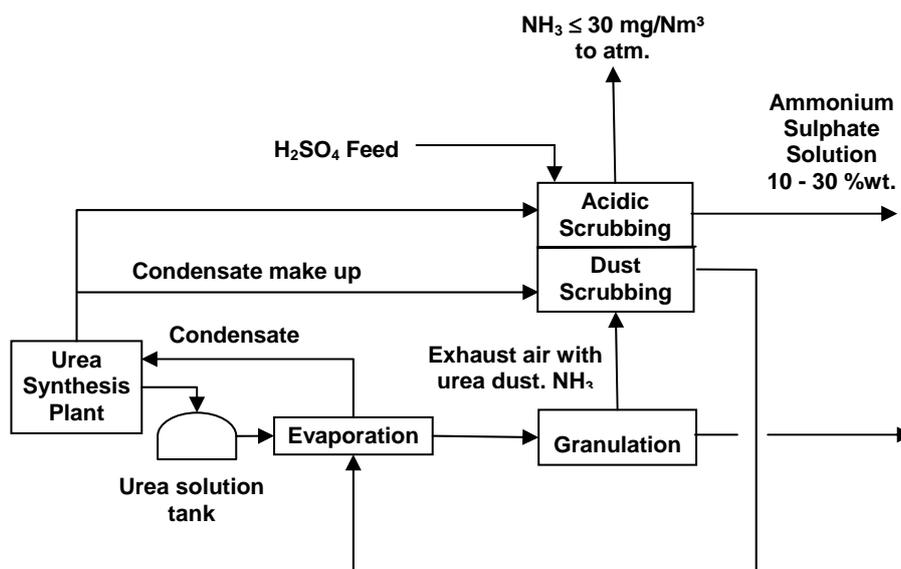


Figure 6 Conventional Acidic Scrubbing System

5.3 Ammonia Convert Technology

The objectives for the development of the UFT proprietary Ammonia Convert Technology were:

- Reduction of ammonia emission by at least 80%
- System to be simple and reliable
- No side stream of scrubbing solution of acidic scrubber
- No contamination of the urea synthesis with ammonia salts
- Overall economics to be feasible

Based on these objectives and the experience gained from acidic scrubbing systems, the scheme shown in Figure 7 has been developed.

In the granulation plant an additional acidic scrubber stage is installed downstream of the dust scrubber. This is to ensure that only a nearly dust free gas flow enters the acidic scrubbing stage. Otherwise the urea would be decomposed by the acid. The ammonia is absorbed in the acidic scrubbing system and is converted into ammonium sulfate.

The bleed of the combined scrubbing system is sent to a small evaporation unit, consisting of a single stage vacuum evaporator. In this small evaporation unit the urea solution containing the ammonium salt is concentrated up to the urea content required for granulation and is subsequently mixed with the 'fresh' urea solution coming from the vacuum evaporation unit of the urea synthesis plant.

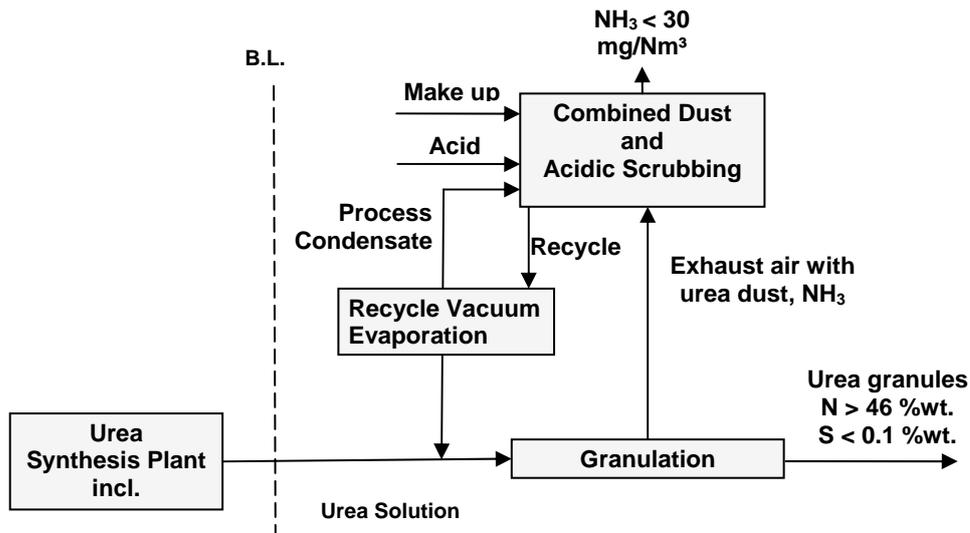


Figure 7 - UFT proprietary Ammonia Convert Technology (ACT)

To avoid entrainment of sulfur and/or sulfuric acid into the urea synthesis plant, the vacuum section of the small evaporation stage and the process condensate from the vacuum condenser are separated from the urea synthesis plant. The vapors of the small evaporation unit are condensed and used as make up for the combined acidic and dust scrubbing system. Depending on the composition of the incoming urea solution from the urea synthesis plant additional condensate make-up with clean condensate might be required.

The process vapors of the vacuum evaporation in the urea synthesis plant are returned to the desorption and hydrolysis section of the urea synthesis plant.

The result is an ammonia concentration in the off gas from the granulation of less than 30 mg/Nm³ of air.

The separation of the recycle flow from the urea synthesis plant has some interesting aspects :

Evaporation section:

- Same total evaporation load, but split over a big and a small evaporation unit
- In total same steam and cooling water consumption

Desorption & Hydrolysis:

- Reduced load on desorption / hydrolysis section, means
- Lower investment cost (smaller equipment)
- Less steam consumption

For existing plants the proposed scheme makes spare capacities available in the existing evaporation section as well as in the desorption and hydrolysis section, because there is less condensate to be

treated. The spare capacity gained is about 15% of the total plant capacity. So the ammonia convert technology is an excellent revamp option.

What about the product?

Urea granules consist of urea incl. biuret, formaldehyde and moisture. The market requirement is for 46 %wt Nitrogen minimum, which corresponds to 98.57 weight % urea. The remaining 1.43 %wt are additional urea, formaldehyde and moisture and typically contains 0.45% formaldehyde, 0.2 % moisture and 0.78 % urea incl. biuret.

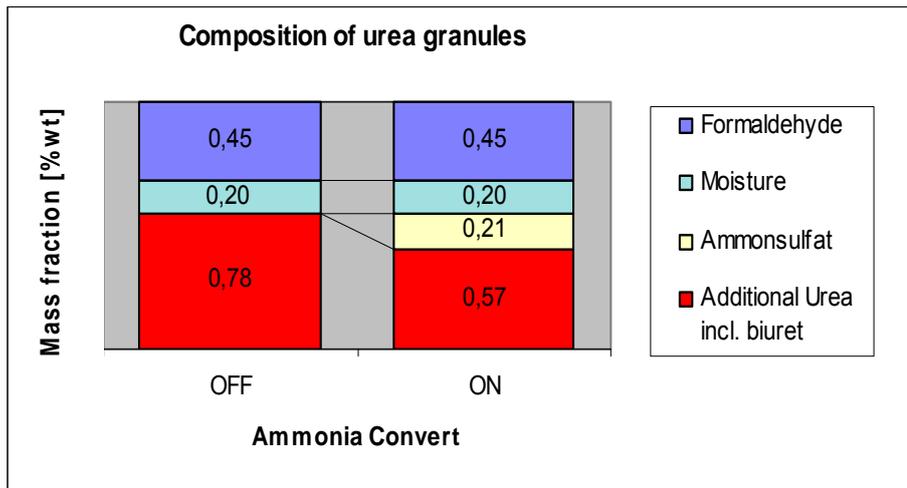


Figure 8 – Comparison of product composition

If the Ammonia Convert Technology is applied, a part of the urea is replaced by ammonium sulphate. The resulting sulfur content in the final product is than roughly one quarter of the ammonium sulphate content. Under typical operating conditions the sulphur content in the product will be about 0.05 wt. %.

5.4 Comparison of Ammonia emission reduction systems

In Table 3 the various NH₃ emission reduction systems are compared. To completely meet current and expected emission regulations for NH₃ an acidic scrubbing system must be installed. Acidic scrubbing systems deliver a bleed stream containing an ammonium salt. This bleed can be processed externally or integrated into the urea production. The latter option is implemented in UFT Ammonia Convert Technology, which as a consequence has the lowest operating costs of all options

Reduction system	Ammonia Abatement	Acidic Scrubbing	Ammonia Convert Technology (ACT)
Emission reduction by	25 to 40 %	> 80 %	> 80 %
Waste stream	None	Approx. 2 kg AS/mt urea as 30 - 40% solution	None
Operations	Easy	Easy	Easy
Additional investment	Low	Moderate	Cost efficient
Operating cost	Low	Moderate	Minimum

Table 3 – NH₃ emission reduction systems

When the Ammonia Convert Technology is implemented there is, beside the positive impact on emission reduction, a remarkable economical impact as well. The market pays for 46 %wt nitrogen in (granular) urea, but the actual nitrogen content is higher and reaches usually close to 46.3 %wt. This means there is a surplus of urea added to the product, which the producer does not get paid for. By adding ammonium sulfate part of the surplus urea is replaced by the ammonium sulfate. The production cost for the ammonium sulfate produced in the Ammonia Convert process is much lower than for urea.

The additional investment required for the Ammonia Convert Technology is an additional acidic scrubbing stage, a sulfuric acid dosing system and some modifications in the evaporation and condensation / vacuum section. This is easy to consider for the design of a new grass root plant and is possible to be implemented in an existing plant as well.

The financial pay-off time of the system is a few years only and from then onwards there is a positive cash flow. The return of investment with respect to image and acknowledgement by the customer and in the community is for the lifetime of the plant.

6 Options during Revamp or Debottlenecking

Frequently when plants are revamped or modernized the existing scrubbing system is a bottleneck. Apart from the desired capacity increases which entail higher air flows, new emissions limits must also be considered. Such a situation was faced by one of UFT's clients recently

Objective

- Nameplate capacity to be increased by 20%
- Usage of existing equipment to maximum extent
- Minimum of shut down time for modifications
- Minimum investment costs for new / modified equipment

- No compromise on product quality and environmental aspects

Problems:

- Layout restrictions for new / exchanged equipment
- Steel and concrete structure restrictions
- Increased pressure drop of scrubbers due to requirement of higher fluidization air flows
- Limited spare capacity of major rotating equipment, especially scrubber exhaust fans

Approach:

- Enlargement of static equipment to the optimum usage of available space inside the building considering refined distribution of cooling duties
- Replacing the internals of the existing high pressure drop Venturi-type scrubbers with two stages of low pressure drop structured packing type.

The use of the structured packing reduced the pressure drop of the existing scrubber to about 1/3 of the original value. In this case the new increased air flow can be handled by the existing scrubber and the existing scrubber exhaust fan.

The new internals are arranged in two stages, therefore one stage could be used for a acidic scrubbing if required at a latter stage.

7 Summary

The ammonia emission reduction technologies available have all one or another draw back. Either the achievable reduction is limited (ammonia abatement system) or a waste stream is generated, which can not be treated economically in a stand alone ammonia/urea complex

The proposed Ammonia Convert Technology is based on an acidic scrubbing stage and a recycle of the obtained ammonium salt into the final product. This allows reduction of ammonia emission to very low levels, while at the same time avoiding an unwanted liquid waste stream.

The Ammonia Convert Technology is beneficial to the environment as it reduces ammonia emissions drastically. At the same time production cost for granular urea can be reduced. Finally a urea fertilizer as produced, which gives added value to the consumers due to the content of micro nutrients while still supplying a nitrogen content of min. 46 %wt.

8 Reference List of UFT Fluid Bed Urea Granulation Plants with Ammonia Emission Reduction Systems

Date of Order	Client	Location	Capacity (MTPD)	Ammonia emission reduction scheme applied
2011	OLAM	Port Gentil, Gabon	3,850	Ammonia Convert Technology
2011	SAMUR	Malaysia	3,850	Prepared for Acidic Scrubbing
2010	Petrobras	Tres Lagoas, Brazil	3,600	Ammonia Convert Technology
2009	Qatar Fertilizer Co. (Qafco VI)	Mesaieed, Qatar	3,850	Ammonia Abatement System
2009	Ruwais Fertilizer Industries (Fertil II)	Abu Dhabi U.A.E.	3,500	(Acidic Scrubbing – under discussion)
2009	CF Industries	San Juan de Marcona, Peru	3,850	Acidic Scrubbing
2009	Hengam Petrochemicals	Bandar Assaluyeh, Iran	3,250	Acidic Scrubbing
2008	Algeria Oman Fertilizer Company (AOFI)	Arzew, Algeria	2 x 3,850	Acidic Scrubbing
2008	Qatar Fertilizer Co. (Qafco V)	Mesaieed, Qatar	3,850	Ammonia Abatement System
2006	Ruwais Fertilizer Industries (Fertil I)	Abu Dhabi U.A.E.	2,500	Ammonia Abatement System (Acidic Scrubbing – under discussion)
2005	Sohar International Urea & Chemical Industries S.A.O.C. (SIUCI)	Sohar, Oman	2 x 1,750	Ammonia Abatement System
2003	Saudi Arabian Fertilizer Co. (Safco IV)	Al Jubail, Saudi Arabia	3,600	Prepared for Acidic Scrubbing
2002	OMIFCO	Sur, Oman	2 x 2,530	Ammonia Abatement System
2001	Saudi Arabian Fertilizer Co. (Safco III)	Al Jubail, Saudi Arabia	1,800	Acidic scrubbing, by owner
2001	China National Off Shore Oil Corp.	Basuo (Hainan), P.R. China	2,700	Ammonia Abatement System
2001	Qatar Fertilizer Co. (Qafco IV)	Mesaieed, Qatar	3,500	Ammonia Abatement System
2000	Petrochemical Industries Company (K.S.C.)	Shuaiba, Kuwait	1,750	Ammonia Abatement System
1999	NamHae Chemical Co.	Yochon, (Yosu) South Korea	1,500	Acidic Scrubbing
1998	FertiNitro S.A.	Jose, Venezuela	2 x 2,200	Ammonia Abatement System
1998	Incitec Ltd.	Gibson Island Australia	950	Ammonia Abatement System

Date of Order	Client	Location	Capacity (MTPD)	Ammonia emission reduction scheme applied
1998	Petrochemical Industries Company (K.S.C.) (PIC)	Shuaiba, Kuwait	1,750	Ammonia Abatement System
1997	Saudi Arabian Fertilizer Co. (Safco II)	Al Jubail, Saudi Arabia	1,800	Acidic scrubbing, by owner
1996	Petronas Fertilizer Sdn. Bhd. (PFK)	Kedah, Malaysia	2,000	Ammonia Abatement System
1996	Yara Belle Plaine (formerly Saskferco Inc.)	Belle Plaine, Saskatchewan, Canada	Revamp to 2,850	Acidic Scrubbing (by owner, with Nitric Acid)
1996	Yara Sluiskil B.V.	Sluiskil, The Netherlands	Revamp to 1,050	Acidic Scrubbing
1978	Yara Sluiskil B.V.	Sluiskil, The Netherlands	800	Ammonia Abatement System
1975	Yara Sluiskil B.V.	Sluiskil, The Netherlands	150	Acidic Scrubbing

9 Literature

1. World Bank, "Pollution Prevention and Abatement Handbook, 1998
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5. "Eliminating the dust at plants and terminals" , Fertilizer International 443(2011) 7-8, pg 18f
6. Kayaert / Niehues, "Ammonia Emission Abatement in a Fluid Bed Urea Granulation Plant", IFA Technical Conference, 2000