CLEANING UNITS
PROCESS AND EQUIPMENT FOR DUST/AMMONIA REMOVAL FROM UREA GRANULATION SYSTEMS

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Introducing an emission control system to a chemical plant is a considerable burden. It not only presents a substantial investment but also raises the running costs. However, both investment and running costs can differ radically depending on the equipment used and technology applied. In the face of strong demand for environment friendliness and effective use of power it is then an issue of utmost importance to pick the right emission control solution, the one that can guarantee, if not a full return on the investment, then at least cutting the cost to absolute minimum.
PROZAP Engineering Ltd boasts years of experience in designing and execution of CLEANING UNITS for gases coming mainly from urea and ammonium nitrate granulation systems. The expertise in the field is confirmed by over thirty implementations of the PROZAP CLEANING UNIT in industrial units with capacity of up to 1,200,000 Nm^3/hr and not only new, but also existing, relatively old plants. Let us review various aspects of abatement of urea dust and gaseous ammonia emissions from urea plant finishing sections with Maria Skorupka, PROZAP's President&CEO.

1 Emission control from urea prilling towers and granulators

Exit air from urea prilling towers and especially granulators contains urea dust in quantities far above the limits defined in the current regulations concerning environment protection. The air also contains gaseous ammonia and again, its concentration in most cases does not comply with the law (Fig.1).

Granulation method	Dust content	Ammonia content	Temperature	Dust distribution
Urea Prilling tower	80-220 mg/Nm^3	60-200 mg/Nm^3	60-85°C	1÷2 µm ~45%
Urea Granulator	up to 12 g/Nm^3	60-180 mg/Nm^3	100-110°C	1÷1000µm
Urea Granulator Cooler	up to 4 g/Nm^3	*traces*	60-80°C	1÷100µm

Fig.1. Average dust and ammonia content ratios, temperatures and dust distribution in off-gases coming from urea prilling towers and granulators

Figure 2 presents current emission requirements for urea dust and gaseous ammonia.

Granulation method	Unit	New plant	Existing plant
Urea Prilling Tower	mg/Nm^3	50	80
Urea Granulator	mg/Nm^3	50	80

Fig.2. Current emission requirements for urea dust and gaseous ammonia

In numerous cases local authorities, which issue a building permits for new plants or allow the existing units to continue operation, make the regulations even more restrictive: 25 mg/Nm^3 of urea dust and 25 mg/Nm^3 of ammonia. This ever more restraining law necessitates cleaning the off-gas from urea granulation systems to remove urea dust and ammonia.

The granulation and quantity of the dust as well as the amount of gas to be treated (500,000 – 1,200,000 Nm^3/hr) require applying a process and equipment that would compensate to the highest possible extent the investment and operating costs.

2 Process of dust and ammonia removal for exit air from prilling towers, granulators and granulator cooler.

In order to remove urea dust and ammonia, wet processes are generally applied. The available technologies vary with regard to the scrubber design, type of demisters and the gas moisturizing/spraying system.

The important characteristic of the process applied in the CLEANING UNIT by PROZAP, the scrubber and demisters design, is a low pressure drop of approx. 800 Pa, which results in relatively low energy consumption for transporting of such a considerable amount of gas.

While selecting the right dedusting system and accompanying equipment the following aspects should be considered:

- ◆ Quantity of gas to be treated,

- Dust and ammonia content,
- The temperature of gas,
- Whether only urea dust or urea dust and ammonia is to be removed, and in case the emission of both pollutants should be controlled, whether they are to be recovered as one or two separate streams.

The technical solution for the urea dust and ammonia emission abatement in prilling towers and granulator coolers differs considerably from this for urea granulators:

- The air coming from prilling towers contains relatively small amounts of the dust and ammonia (see Fig. 1) and the gas temperature, in practice, does not exceed 85°C.
  The air coming from granulator coolers has a higher dust content (of up to 4g/Nm^3) and the temperature not exceeding 80°C. The air does not contain ammonia. For this cases, single-stage scrubber, described in detail in p. 3.1 is recommended.
- The air coming from granulators contains significant amounts of dust (up to 12g/Nm^3) and its temperature varies between 100 and 110°C. The ammonia content is also considerable, more than 50mg/Nm^3, thus exceeding the allowed emission. For this case, the solution described in point 3.3 is recommended.

3 Applications of PROZAP CLEANING UNIT system

3.1 Urea prilling towers and granulator coolers

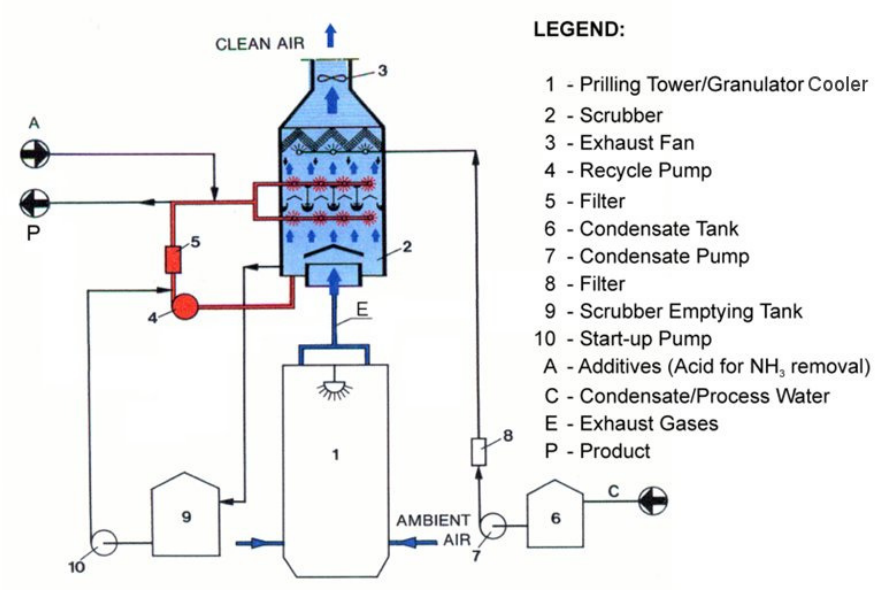

Fig.3. Single-stage scrubber by PROZAP (Poland)

Fig.3. shows the unit with a single-stage scrubber (2) removing the dust or simultaneously dust and ammonia. The scrubber has two circulation and spray circuits. In one there circulates

aqueous urea solution (U) or/and aqueous solution of urea and ammonium sulphate (UAS), alternatively aqueous solution of urea and ammonium nitrate (UAN) depending on the kind of acid used to bind ammonia. The circulating solution is pumped by a pump (4) via a filter (5). In the second circuit there is process water, used to continuous flushing of the demisters and diluting the solution to the required concentration. The water is fed from the tank (6) by the pump (7) through the filter (8).

In order to remove ammonia, sulphuric or nitric acid addition is used depending on which is available and what use for the retrieved product is projected.

The products are:

- urea aqueous solution up to 25 %wt concentration, if only dust is removed,
- urea and ammonium sulphate aqueous solution (UAS), or urea and ammonium nitrate aqueous solution (UAN) up to 25 %wt, in case of simultaneous removal of dust and ammonia.

3.2 Urea prilling towers – double-stage scrubbers

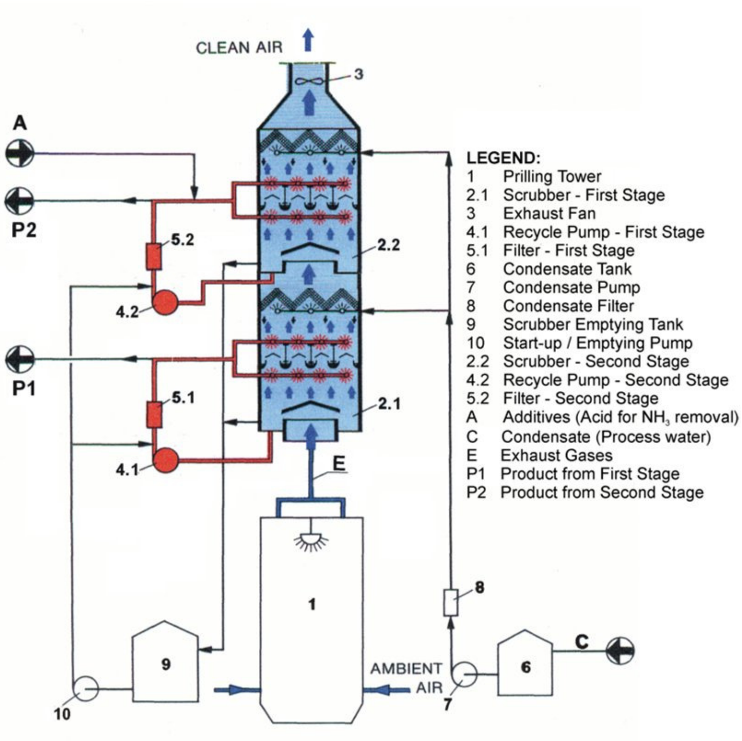

Fig.4. Double-stage Scrubber by PROZAP (Poland)

The process here is analogical to this with a single-stage scrubber and is shown in Fig.4. Double-stage scrubbers are used when there is a demand from the client to remove from the cleaned air stream urea and ammonia separately.

- First stage (2.1) removes the urea dust.
- Second stage (2.2) removes ammonia.

Each stage includes two circuits but there are some differences:

- At the first stage in one circuit there is urea solution of up to 25 %wt and process water in the other,
- At the second stage, in one circuit there is ammonium sulphate (AS) or ammonium nitrate (AN) concentration up to 25%wt depending on which acid was added in order to remove ammonia. In the other circuit there is process water.

Double-stage scrubbers are more expensive investment-wise and generate higher running costs mainly due to doubled power consumption needed to push the gases through the system.

The products of double-stage pollution removal are:

- Aqueous urea solution, concentration up to 25%wt,
- Aqueous solution of ammonia sulphate (AS) or ammonium nitrate (AN), concentration up to 25%wt. The solution may also contain a small amount of urea.

3.3 Urea granulators

As it was mentioned earlier, the air coming from granulators contains large amounts of dust and its temperature exceeds 100°C. The granulation of the dust is above 1µm to 1000µm, so the particles are large, as opposed to the dust coming from prilling towers.

Two stages/circuits of spraying with urea solutions are used.

During the first stage, intense spraying with concentrated urea solution (approx. 45% wt.) is used. This is also favourable with regard to recycling of the recovered urea product back to production.

During second stage, the spraying is less intense and the urea solution of approx. 5% is used. Process water / process condensate is sprayed upstream the demisters. The excess solution from the second stage spraying is directed to the first stage of spraying. It is also possible to moisturize the air before it enters the scrubbers.

The process is illustrated in Figure 5.

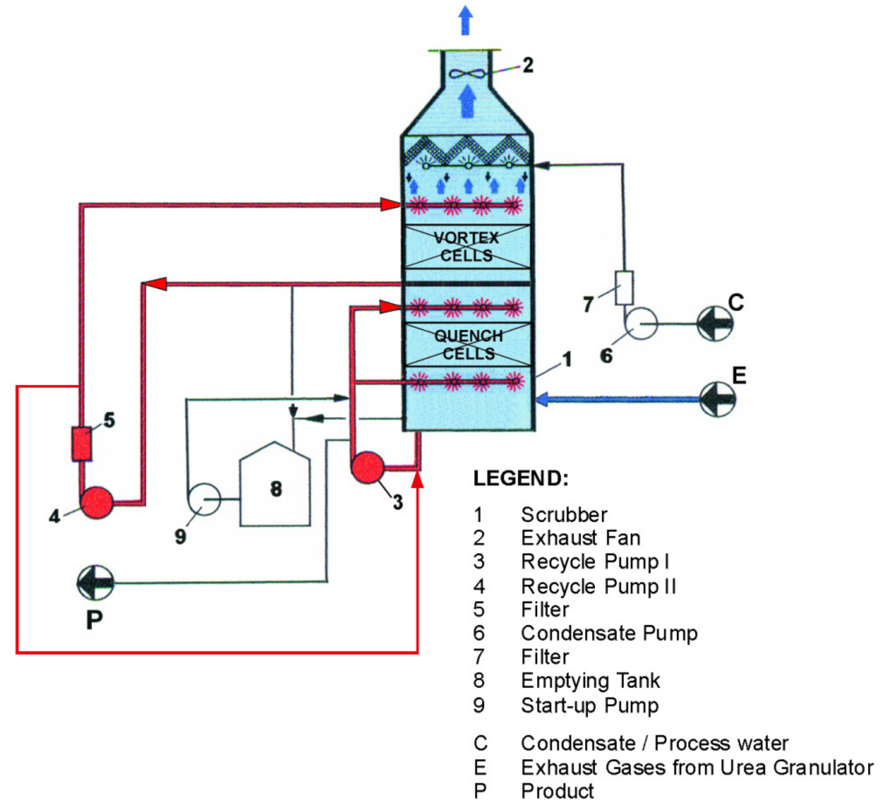

Fig. 5. Cleaning the air coming from urea granulators in the CLEANING UNIT by PROZAP (Poland)

If ammonia is to be removed from the gas stream, sulphuric or nitric acid is added to the second circulation loop. The products obtained in this way are:

- ~45% wt solution of urea,
- Ammonium sulphate or ammonium nitrate solution with a slight urea content.

4 Feedstock and utilities used in a typical CLEANING UNIT application. Advantages of the system.

- Process water (process condensate from a urea plant or demineralised water). The consumption depends mainly on ambient temperature and gas humidity. Process water is used mostly for flashing in the treated air, practically to the saturation point and for diluting of the product.
  - Sulphur or nitric acid to bind ammonia – stoichiometric amounts used.
  - Electric power for fans and pumps – consumption approx. **1 kWh / 1000 Nm^3** of treated gas.
  - Instrument air for the pneumatic control systems.
  - Heating steam at 3-5 bar, used occasionally to flush the spraying nozzles.

PROZAP's CLEANING UNIT system is unique due to the following characteristics:

- Low energy consumption for transporting of the gases through the system.

  The pressure drop in PROZAP's single-stage scrubbers is 800 Pa and 1600 Pa in double-stage version, thus being approximately three times lower than in other systems:

  - Pressure drop in a sieve tray scrubber: approx 3,000 Pa

  - Pressure drop in a 'turbulaire' type of scrubber: 3,500 Pa

  These parameters are directly related to the consumption of energy required to transport the gas through the system: the lower the pressure drop, the lower consumption of energy, for example:

Parameter	SieveTray Scrubber	Turbulaire	CLEANING UNIT
Pressure drop (Pa)	2794	3556[1]	up to 800
Power Consumption ($kW/1000Nm^3$)	Expected: 3.5	Expected: 4.5	1

Fig.6. Examples of pressure drops in scrubbing systems.

Below, there is a simplified calculation of possible savings on energy consumption due to application of the CLEANING UNIT by PROZAP.

Assumptions for calculations:

- Energy consumption by 1 CLEANING UNIT: $1kW/1000Nm^3$
- Inlet flow to emission control unit: 1 200 000 Nm^3/h
- Operation period: 8000h/year
- 1MW ≈ €50 (European average)

kW/h	kW/year	€/year
1200	9,600,000	480,000

Fig.7. Exemplary, yearly cost of energy for the CLEANING UNIT by PROZAP.

As the above examples show, thanks to the low pressure drop in PROZAP's CLEANING UNIT, substantial energy saving of 1 000 000 EUR and more can be expected, as compared to other scrubbing systems.

- PROZAP's process is very effective with regard to removing low-granulation dusts, like those present in urea and especially ammonium nitrate prilling towers. The efficiency figure is over 90%. Dust and gaseous ammonia content in the gas leaving the scrubbing system is 25 mg/Nm3 each.

[1] http://www.babcock.com/library/pdf/ps-420.pdf

Placing the elements of the CLEANING UNIT system

In the case of prilling towers, the most beneficial is placing the scrubbers on top of the tower, as shown in Fig.8 and Fig.9.

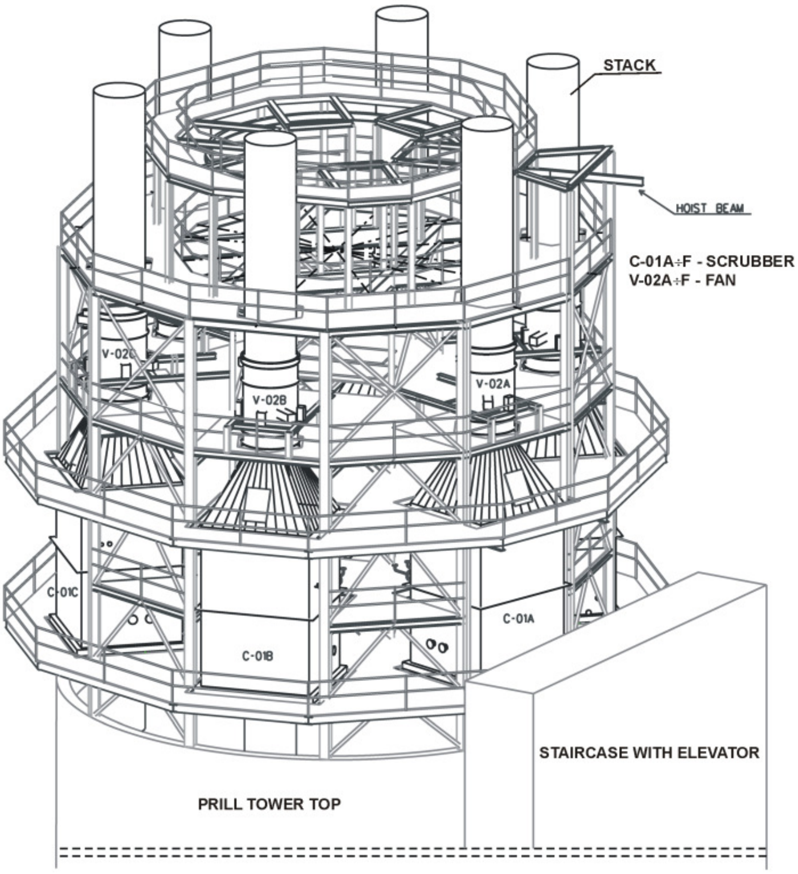

Fig.8. Placing scrubbers on top of a prilling tower

Fig.9. CLEANING UNIT for Ammonium Nitrate Prilling Tower designed by PROZAP

There is a possibility to place the equipment on the ground level but it is less efficient with regard to both, investment and operation. This application is shown in Fig.10.

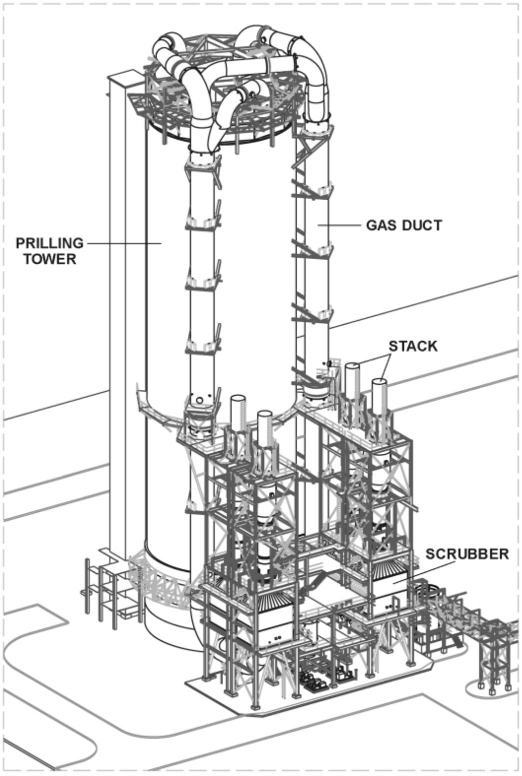

Fig.10. Placing PROZAP's CLEANING UNIT scrubbers on the ground level

In case of granulators and granulator coolers, the scrubbing system is placed on a steel structure at elevation +6m.

As a rule, it is most advantageous to place the scrubbers in the close vicinity of the source of gases to be treated.

Processing of solutions to solid fertilizers

The solutions supplied as products by the CLEANING UNIT system, i.e. ammonium sulphate solution (AS) and urea and ammonium sulphate solution (UAS), can be processed into solid fertilizers. As a result of crystallization of UAS, a mixture of urea and ammonium sulphate crystals is produced. This mixture can be further processed with rotoform into pellets. Urea present in the mixture acts additionally as a binding agent for the ammonium sulphate crystals.

5 Other applications of the PROZAP CLEANING UNIT system.

The process utilized by PROZAP in their CLEANING UNIT system can be and is applied in order to:

- Removing the dust and ammonia from ammonium nitrate prilling towers and evaporators. Those gas streams contain very fine dusts and frequently aerosols, but even so, the gas leaving the CLEANING UNIT contains 25 mg/Nm3 of ammonia and 25 mg/Nm3 of ammonia nitrate.
- Removal of SO_2, SO_3 and sulphuric acid vapour and mist from sulphuric acid plants as well as power plant flue gas.

6 Conclusion

CLEANING UNITS by PROZAP Engineering Ltd are state-of-the-art solutions offering remarkable benefits for the chemical plant owner:

- Future-proof - compliance of the plant with restrictive environmental regulations today and beyond. Emission reduction to 25 mg/Nm^3 of dust and 25 mg/Nm^3 of ammonia.

- No limitations as to the capacity of the plant and the amount of off-gases to be treated.

- Substantial power saving due to a radically lower pressure drop.

- Fits well both new and old plants.

- Operating expenses resulting from installation of a CLEANING UNIT on a prilling tower have hardly any effect on the cost of production (approx.1 USD/tonne, depending on the plant capacity and the price of electrical power). In case of a CLEANING UNIT for a granulator this effect is even smaller due to higher urea content ratio in the treated gases.

About PROZAP Engineering Ltd

PROZAP Engineering Ltd is one of the major multi-discipline engineering companies in Poland. The company started in 1970 as the Design and Engineering Department of Zakłady Azotowe "Puławy", employing engineers and technicians involved in designing and erection of the industrial complex. In 1988 the Design and Engineering Department was transformed into a commercial company PROZAP Engineering Limited. Presently, the company renders engineering services for many domestic and foreign companies and institutions. The basic scope of the company's activities includes elaboration of technical documentation at various stages of the investment life cycle, procurement and participation in construction. PROZAP services cover a complete, investment services package: from an idea, through designs and engineering, to supplies and plant erection, extending ever further to management and supervision over start-up and as-built documentation, according to individual requirements of each client. High quality of services rendered by PROZAP is assured by Quality Management System according to ISO 9001:2009 implemented in 1998 and still valid, certified by System & Services Certification SGS Polska.PROZAP Engineering Ltd.