Nitrate fertilisers
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1. Company profile

With its highly specialised workforce of more than 5,600 employees and its international network of subsidiaries and branch offices, Uhde, a Dortmund-based engineering contractor, has to date successfully completed over 2,000 projects throughout the world.

Uhde’s international reputation has been built on the successful application of its motto Engineering with ideas to yield cost-effective high-tech solutions for its customers. The ever-increasing demands placed upon process and application technology in the fields of chemical processing, energy and environmental protection are met through a combination of specialist know-how, comprehensive service packages, top-quality engineering and impeccable punctuality.
2. Uhde – The right choice

Uhde can look back on more than 80 years of experience in the fertiliser sector, during which time the company has engineered more than 360 plants.

With today’s intensive agriculture, soil yields are very much a matter of choosing the right type of fertiliser. Selection criteria for the wide range of different grades now available include soil type, climate and crop type. This, in turn, reflects the need for high-quality fertiliser production. Choosing the right process is of the essence.

Uhde offers proven, competitive processes based on both proprietary and renowned licensed technologies, thus putting us in a position to offer a full range of plants for the production of single-component and mixed nitrogenous fertilisers.

The diagram on the right (Fig. 1) provides an overview of the principal fertiliser production routes, as well as the available processes and main licensors.

This brochure deals only with the key processes offered by Uhde for the production of nitrate fertilisers.

For our urea, nitrophosphate, compound fertiliser, nitric acid and ammonia processes, please refer to our separate brochures.
3. The Uhde ammonium nitrate neutralisation technology

Ammonium nitrate neutralisation is a proprietary Uhde process, designed for maximum reliability and safety. This well-proven technology is the basis of our nitrate fertiliser technology portfolio and has been used successfully by our customers in more than 40 commercial-scale plants for about 40 decades now.

**General**

Ammonium nitrate is produced from gaseous ammonia and aqueous nitric acid in an exothermic reaction according to the following equation:

\[ \text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3 + \text{H}_2\text{O} \]

The heat of reaction is released into the circulating stream of AN solution, causing a temperature rise. Precise control of the reaction system parameters is essential for highly-efficient ammonium nitrate production. These parameters include in particular good mixing in of the reactants as well as reliable temperature and pH control. The Uhde technology comprises an external circulation loop, either forced or natural, and also a sophisticated reactant feed and mixing system for stable operating conditions.

Uhde offers two proprietary types of neutralisation processes for the production of ammonium nitrate solution:

**Vacuum neutralisation and evaporation**

This process is the most popular alternative because it involves the lowest investment costs. The reaction takes place in a slightly pressurised neutraliser to prevent the ammonium nitrate solution from boiling in the mixing and reaction sections thus minimising ammonia losses. Subsequently, the solution is flashed into a vacuum through a restriction orifice adjacent to the vapour separator, thereby utilising the reaction heat for water evaporation. A solution concentration of 95 wt.% can be achieved with a preheated feed of 60 wt.% nitric acid. For control and safety reasons, however, the AN solution concentration is mostly limited to 92 wt.%.

The higher concentration necessary for further process steps, such as granulation (Section 4) or prilling (Section 5) is achieved by steam heating the solution under vacuum pressure. For optimum process control and stability, Uhde preferably applies a thermosyphon evaporation system. The scrubbed process vapours are used for feedstock preheating; surplus vapours are condensed.

**Pressure neutralisation**

In order to utilise the heat of reaction more efficiently, the process vapour system in this case operates above atmospheric pressure. Uhde offers two main pressure neutralisation alternatives for effective heat recovery:

a) The heat of reaction stored in the hot ammonium nitrate solution leaving the neutraliser is used direct for the final concentration stage. Even if a final concentration of 97 wt.% is required, there is no need to import additional steam. (Fig. 3)

b) Heating steam is imported for final concentration of the ammonium nitrate solution, while part of the heat of reaction is utilised to generate low-pressure steam at approx. 5 bar abs. (Fig. 4)

In both cases the flash steam from the vapour separator at 2 - 4 bar abs is used for intermediate concentration of the weak ammonium nitrate solution. Again, the remaining process vapours are used for feedstock preheating; surplus vapours are condensed. Depending on how the vapour condensate is to be used, some or all of the vapours need to be scrubbed before condensation in a separate vapour scrubber.
Fig. 2: Vacuum neutralisation and evaporation

Fig. 3: Pressure neutralisation with direct heat recovery

Fig. 4: Pressure neutralisation with clean steam production
Uhde can also offer a third-party ammonium nitrate process, for example the INCRO pipe reactor process, if required.

**Pipe reactor process**

In this process ammonia and nitric acid are mixed in a long pipe equipped with internals. The heat of reaction immediately produces water vapours which cause a rapid flow through the pipe with a high degree of turbulence. In a downstream separator the flow is split into vapours and ammonium nitrate solution. The solution is fed into a flash tank before being pumped to the concentration stage while the vapours are scrubbed prior to further utilisation. The reaction process typically operates at pressures of 4 - 5 bar abs and the vapours can thus be used for further solution concentration and other heating purposes.

Uhde has already constructed and successfully commissioned licensed pipe reactor technology.

**Vapour scrubbing**

The vapours formed in the ammonium nitrate neutralisation and evaporation process are scrubbed either direct in the vapour separator or in a separate scrubbing column. Depending on the quality of the process vapours, a single or dual-stage scrubber is applied. The condensed overhead vapours from the scrubber can be used for various purposes, e.g. as scrubbing make-up water or as feed for a demineralised water plant. Contaminant levels in the clean condensate are as low as 15 ppm nitrogen. The sump concentrate can be used for nitric acid make-up.
Ammonium nitrate vacuum neutralisation and evaporation unit for Enaex S.A. in Mejillones, Chile.
Capacity: 1,060 t/day AN solution (92/96 wt.% AN)

<table>
<thead>
<tr>
<th>Consumption figures (expected)</th>
<th>Vacuum neutralisation</th>
<th>Pressure neutralisation 2 bar abs with direct heat recovery</th>
<th>Pressure neutralisation 4 bar abs with clean steam production</th>
<th>Fig. 2</th>
<th>Fig. 3</th>
<th>Fig. 4</th>
<th>Fig. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam import (4.5/10 bar a)</td>
<td>kg/t&lt;sub&gt;AN&lt;/sub&gt;</td>
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<td>10</td>
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<td>90</td>
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<tr>
<td>Steam export (6.5/4.5 bar a)</td>
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<td>Cooling water</td>
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<td>22.5</td>
<td>3.8</td>
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</table>

Remarks: Figures for 60 wt.% nitric acid feed, 96 wt.% AN product, cooling water at T = 10°C, electrical energy without DCS, lighting, CR AirCon, limestone grinding, etc.
General

Today modern fertiliser plants supply granulated products. Prilling is becoming less common due to environmental constraints and increased product quality requirements.

In producing fertiliser from the various solid and liquid feed materials, the granulation unit must ensure that the resulting product meets market requirements with regard to its chemical and physical properties.

There are many different ways of producing granules, such as flaking, drum, pan or pugmill granulation and fluid-bed technology.

In the past, Uhde has built granulation plants for all common fertiliser grades from straight N fertiliser to NP(K) and P(K) fertilisers. Uhde has a wealth of experience in the design and operation of granulation plants and is in a position to build plants based on all modern granulation processes.

The most common granulation process used in nitrate fertiliser plants built by Uhde is the proprietary Uhde pugmill granulation process.
Pugmill granulation unit for the Irish Fertilizer Company (IFI) in Arklow, Ireland.
Capacity: 1,400 t/day CAN granules (27.5 wt.% N).
The core component of Uhde’s own granulation process is a pugmill granulator. A pugmill or blunger is a horizontal mixing and agglomeration device. Its design is based on a horizontal U-type trough with dual shafts and paddles extending the length of the trough. The rotation of the pitched paddles moves the product from the bottom of the trough up through the centre. As a result of the speed at which the paddles rotate, the granules are fluidised in the upper part of the granulator.

All solid feeds (e.g. filler or additives) and the recycle material are added at the front of the pugmill to ensure sufficient mixing before the liquids are added. The liquid feed (e.g. ammonium nitrate melt) is distributed over the fluidised material using a proprietary distributor.

In the granulator the material is built up to size through agglomeration and layering. The hot, moist granules leaving the granulator drop through a chute into the rotary drying drum. In the drying drum the granules are dried by means of hot air. The dried granules are then screened into oversize, on-size and undersize fractions by double-deck or single-deck screens. The undersize fraction is returned to the granulator immediately; the oversize fraction is crushed beforehand.

The on-size, or product, fraction is cooled in a fluidised-bed cooler with conditioned air to a suitable storage temperature.

The cooled product is then passed to a conditioning unit where surface-active substances are applied to improve the handling and/or transport properties (e.g. caking, dusting, etc.).

The waste air of the fluidised-bed cooler is used to dry the product, thus considerably reducing the amount of waste air to be treated. It also reduces power consumption as the products can be dried autothermally or with a significantly reduced heat input by an air heater installed upstream of the drying drum.

Most of the dust in the waste air from the drying drum is removed by cyclones and returned to the granulator. After passing through the cyclones, the air still contains dust and ammonia, which have to be removed in order to comply with environmental regulations.

The waste air from the drying drum and the air from the dedusting system are therefore passed to a wet scrubber. Here, the dust is largely removed from the air by close contact with the scrubbing solution while the ammonia reacts with the nitric acid contained therein.

The bleed from the scrubber is returned to the evaporation system. Therefore, no liquid effluents are produced during normal operation.
Key features

- Flexible with regard to capacity
- Flexible with regard to production of different products e.g. AN, ASN, CAN, CN
- Easy addition of supplementary nutrients (S, Mg, etc.)
- Capacity - installed single-line capacity from 200 to 1,800 mtpd
- Emissions below BAT levels
- No liquid effluents
- Power consumption below 30 kWh/t (depending on product)
- Low air flow

Fig. 6: Uhde pugmill process

Additive

AN melt

Filler (limestone, dolomite)
5. Prilling for low-density ammonium nitrate

Although prilling plants for fertiliser-grade ammonium nitrate have decreased in importance compared to granulation processes, prilling is still the state-of-the-art process for low-density ammonium nitrate. Uhde offers a proprietary technology as well as qualified engineering services for licensed processes.

Low-density ammonium nitrate (LDAN) is used as an effective and cost-efficient mining explosive, mainly as a mixture with fuel oil (ANFO) or in emulsion-type explosives. The high porosity of the LDAN allows good oil absorption, which is necessary for an optimal blasting energy yield. If no additives are used, chemically pure ammonium nitrate can be produced, e.g. as feedstock for medical purposes (nitrous oxide).

Main characteristics of the final LDAN prills:

- Uniform spherical shape
- Nitrogen content > 34.7 wt.%
- Water content < 0.1 wt.%
- Grain size 1 - 2 mm
- Fuel absorption > 6 wt.% (adjustable)
- Free-flowing
- Good thermal resistance to hot climates

For the production of low-density prills the ammonium nitrate melt is pumped to the prilling tower top and mixed with a prilling additive. From here the melt is sprayed in droplets which crystallise in a countercurrent stream of cool air.

The prills are then sequentially dried in two rotating drums, screened, cooled in a fluid-bed cooler and coated with an anti-caking agent. Off-spec material is redissolved and recycled to the process. All air used in the process is scrubbed to meet BAT emission levels. By reusing the cooling air in the drying drums, energy consumption and waste air flow are significantly reduced.

Uhde has designed LDAN prilling plants with single-line operating capacities of 1,250 mtpd and engineered licensed processes of up to 1,060 mtpd.

Uhde cooperates closely with INCRO in the field of LDAN prilling technology.
Ammonium nitrate prilling unit for Queensland Nitrates Pty Ltd., Australia.
Capacity: 400 t/day AN prills (technical grade)
The depletion of sulphur in soils is increasing and this has spurred demand for sulphur-containing fertilisers, such as ammonium sulphate nitrate.

This is particularly attractive as it can be produced in a modified AN or CAN pugmill granulation plant.

Ammonium sulphate nitrate is a double salt which approximately corresponds to the following formula:

\[ 2 \text{NH}_4\text{NO}_3 \times (\text{NH}_4)_2\text{SO}_4 \]

Commercial-grade ammonium sulphate nitrate contains 26% nitrogen and 14% sulphate.

In the Uhde process described below, the ammonium nitrate combines with ammonium sulphate to form ammonium sulphate nitrate. The addition of additives results in a product which is very hard and has excellent storage properties.

An approx. 85% AN solution is fed to a saturator together with sulphuric acid and gaseous NH\(_3\). The ammonium sulphate nitrate melt is formed by the neutralisation of the sulphuric acid with gaseous NH\(_3\) at approx. 160°C.

The heat of reaction liberated through the formation of ammonium sulphate vaporises water contained in the feedstock, thereby causing the ammonium sulphate nitrate solution to reach the required final concentration.

The ammonia-bearing vapours from the saturator are treated in a scrubber, where the ammonia is removed by reaction with nitric acid. The scrubber bleed is returned to the saturator.

ASN can be granulated in a pugmill granulation unit as described on page 14.

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**Fig. 9:** Ammonium sulphate nitrate process
7. Calcium nitrate – CN

Ground limestone and nitric acid of 50-60% concentration are mixed in agitated tanks. The components react to form calcium nitrate solution according to the following equation:

\[ \text{CaCO}_3 + 2 \text{HNO}_3 \rightarrow \text{Ca(NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2 \]

The CO₂ and water vapours liberated by the reaction are withdrawn, and any entrained droplets are removed by the scrubbing system.

Commercial-grade calcium nitrate (CN) contains approximately 5 - 7% ammonium nitrate to improve storage properties. The required AN content can be obtained by neutralising the remaining free acid with ammonia or by adding fresh ammonium nitrate solution.

If CN is used to produce liquid fertiliser, an evaporation step is not needed. Any inerts or other components of the limestone that do not react with nitric acid have to be removed by filtration. The remaining sludge is disposed of.

If granulated product is required, the calcium nitrate solution is sent to an evaporator to obtain the concentration required for granulation.

CN can be granulated in either a drum or pugmill granulation unit to yield well-shaped round granules, the appearance of which is similar to that of calcium ammonium nitrate granules. (see page 14).

The calcium nitrate melt is fed to the granulator via a metering station along with the recycled material (the fines, the crushed oversize, and the dust from the dust-collecting facilities).

The granules are then air-cooled in a cooler.

The cooled product is screened, and the on-size fraction is bagged or sent to the bulk storage area.

The waste air from the cooler is treated in a wet scrubber before being discharged to atmosphere.

**CN solution from nitrophosphate production**

The nitrophosphate (ODDA) route for the production of NP(K) fertiliser produces CN solution as a by-product. This solution, too, can be used to produce CN granules or liquid CN fertiliser.
8. Liquid N fertiliser – UAN and CN

UAN
The use of liquid fertilisers is a common practice, especially in North America. A fertiliser with excellent physical properties is UAN solution, which is a mixture of ammonium nitrate, urea and water. Standard solutions contain 28, 30 and 32% nitrogen, respectively, but can also be enriched with soluble plant nutrients, such as sulphur, boron and calcium compounds. A typical composition of UAN solution with 32% N is

\[
\text{AN : Urea : H}_2\text{O} = 45 : 35 : 20\%
\]

As UAN solution is a liquid with a low viscosity, it can easily be applied by spraying without the need for additional irrigation. Depending on its composition, the salting-out temperature of the solution can be well below zero degrees centigrade and transport and storage are thus simple even in cold climates.

Uhde has designed UAN plants based on two process alternatives:

a) UAN solution on the basis of ammonium nitrate neutralisation

In this process alternative ammonium nitrate is produced as described in Section 3. Urea solution and water are mixed with the AN solution in a special UAN mixing unit to obtain the required nitrogen content and adjusted to an alkaline pH. After cooling and the addition of a corrosion inhibitor, the final UAN solution can easily be stored and handled.

b) Neutralisation of urea off-gas

When implementing a once-through urea synthesis, the ammonia-rich off-gas can be used to drive the ammonium nitrate neutralisation reaction. Due to the high CO\(_2\) content in the off-gas, the neutralisation reaction is performed in a natural circulation loop, followed by the UAN preparation steps described before. In order to minimise the ammonia losses in the vent gas, a sophisticated scrubbing system is installed, reducing the losses to 0.013 kg\(_{\text{AN}}\)/t\(_{\text{AN}}\).

Contaminant levels in the process condensate used as make-up water for a nitric acid plant are as low as 300 ppm AN and 100 ppm HNO\(_3\).
**CN**

Calcium nitrate solutions are non-pressurised liquids mainly used for drip or irrigation systems in horticulture.

A typical solution is CN·17 with a composition \( \text{AN : CN : H}_2\text{O} = 31 : 36 : 33\% \). This solution is a fast-acting fertiliser containing both nitrate (for quick response) and ammonium nitrogen (for retarding nutrition) while the calcium buffers the pH in the soil.

The production of AN and CN is described in detail in Section 3 and 7, respectively.

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**Fig. 12**: UAN solution process with urea off-gas